Volume 15 JUNE 1931 Number 6

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of the
American Association *of* Petroleum Geologists

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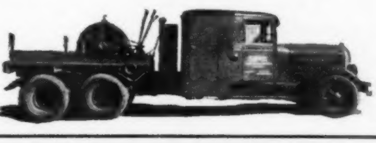

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JUNE 1931

ACCOUNT OF EARLY ENDEAVORS ON ANTICLINAL THEORY IN CANADA[1]

R. B. HARKNESS[2]
Toronto, Ontario, Canada

ABSTRACT

Seepages of oil were reported by the Geological Survey of Canada as early as 1840. Hunt visited the oil wells of Oil Springs, Ontario, in 1860, and in March, 1861, about one month after the first flowing well was drilled, presented his paper in Montreal, in which he outlined the anticlinal theory as now known.

The geological notes in the May *Bulletin* contain a fine tribute by J. V. Howell[3] to the work of the early geologists, and show the astonishing progress that they made in solving the riddle of the origin and accumulation of petroleum, which, until that time, in North America, was dealt with only in bottles and used as a medicine, both externally and internally. This paper is a brief resumé of the work of Canadian geologists in the sixties and earlier.

Although Drake, in 1859, drilled the first oil well in North America, in 1857 wells were *dug* in Lambton County, Ontario, and oil was pumped to the surface, to be refined and sold for illuminating and lubricating oil.

The Geological Survey of Canada was, as late as 1870, fighting to justify its existence. The people expected the Survey to find coal, iron, and precious minerals. Handicapped as he was, William Logan, and

[1]Manuscript received, January 10, 1931.

[2]Whitney Block, Parliament Buildings.

[3]J. V. Howell, "How Old Is Petroleum Geology?" *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 5 (May, 1930), pp. 607-16.

especially T. Sperry Hunt, his chemist and mineralogist, did, according to the standards of present progress and the information then available to them, go very deeply into the subject and thus led the way that was followed by others for many years afterward.

Logan had been shown the seepages of oil at Gaspé in 1843, and, debating on their origin, stated that the petroleum oozed from the rocks along the sides of two anticlines cut by trap dikes. One dike was definitely related to a spring. Aside from satisfying himself that the seepages were associated with two dikes on the anticlines, he reached no further conclusion. This he recorded in his *Report of 1844*,[1] referred to by Howell and illustrated by Hunt in a map published in 1865, a part of which is reproduced as Figure 1. In 1849 Murray's attention was directed to the seepages of oil at Black Creek (later Oil Springs) in the swamps of Enniskillen Township and along the banks of Thames River near the village of Bothwell, Ontario. He submitted specimens of the oil-impregnated clay from Oil Springs to Hunt,[2] who pronounced it "asphaltum, mineral pitch, and mineral caoutchouc." He recommended it for paving and for the manufacture of illuminating gas and oil, evidently believing it to be similar to the Trinidad deposits. He revised this opinion after he made a personal examination in 1860. Murray made a further examination of the locality in 1850 and called these "petroleum springs." He dug some test pits with indifferent results. He concluded[3] that

> the petroleum springs of Bear Creek in Enniskillen (Oil Springs)....of the Thames in Mosa....take their origin from the lower bituminous shales of the Portage and Chemung group.

It is noteworthy that in 1857 W. M. Williams, of Hamilton, Ontario, a Scotchman, using the patent for refining illuminating and lubricating oil of James Young of Glasgow, installed a small still at Black Creek (later Oil Springs) and produced illuminating oil from this impregnated clay until he had exhausted the supply (the area was less than an acre). He then "dug" wells, hoping to tap the source of supply, and at 60 feet reached a gravel bed, from which a substantial supply of oil (which was later used directly as lubricating oil) was obtained. Many of these wells were dug in the years following, both at Oil Springs and at Petrolia, 6 miles north, where another seepage was observed; seventy of these wells had been dug in August, 1861.[4] Therefore Oil Springs was

[1] Pp. 41-44.

[2] *Report of 1850*, p. 99.

[3] *Report of 1853-56*, pp. 131-32.

[4] "Descriptive Catalogue of a Collection of Minerals of Canada and of its Crystalline Rocks, London International Exhibition for 1862," *Geol. Survey of Canada.*

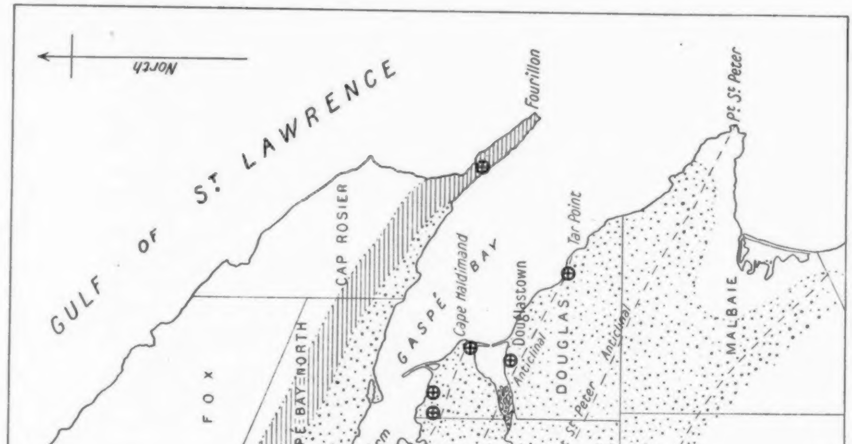

FIG. 1.—Copy of part of map accompanying *Petroleum, etc., in Gaspé*, by T. Sterry Hunt (Quebec, 1865).

the center of the refining industry between 1857 and 1860, when Williams removed his refinery to Hamilton.

Drake drilled his well in 1859; in 1860 Shaw set up a spring-pole drilling rig and commenced a well, which he finished in January, 1861,[1] flowing 2,000 barrels per day (the first flowing well in Canada), at a depth of approximately 165 feet in the rock, or 200 feet below the surface.

One can easily imagine that this phenomenon would intensely interest Logan, Hunt, and Murray, who years before had puzzled over these occurrences. Hunt, who was a very prolific thinker and writer, probably recorded his thoughts. Others, E. B. Andrews in particular, working in Pennsylvania, confirmed Hunt's opinions. These opinions Hunt stated in an address given in Montreal on March 1, 1861; in the *Canadian Naturalist* (July, 1861); *Geology of Canada, 1863;* and in the form of a summary to his *Report of 1863-1866.*

William Logan gave Hunt full credit for most of the work on petroleum in *Geology of Canada, 1863.* Hunt and Murray are the only men of the Geological Survey of Canada who mention having seen the Petrolia and Oil Springs seepages. Charles Robb, a mining engineer in Montreal, read a paper before the Canadian Institute in Montreal on February 9, 1861, describing the surface wells where "recently oil has been obtained by drilling into the rock."[2] He deals in general with the refining industry, states as his opinion that oil is of animal origin, and draws a word-picture of the Devonian seas of that time.

On page 527 of the 1863 report (no doubt Hunt's report), which is quoted on page 601, he gives a concise statement of the probable origin of petroleum, following a discussion of the history of the several occurrences known to him from his personal knowledge and published literature. Most of these occurrences were solid bitumen, and Hunt, no doubt, had only recently been satisfied himself that these had once been liquid and had been altered by volatilization and oxidation. He had probably been puzzling over a source corresponding with the association with quartz crystals, trap, shales, sandstone, and limestone. His conclusion that the origin of this oil is from "marine vegetation or from the remains of marine animals within the limestone itself" is very skilfully worded, and shows that Hunt's knowledge of this subject was in advance of his time.

Here follow extracts from pages 523-27 of the 1863 report, the last paragraph of page 254 and the first two paragraphs of page 255 of the 1866 report.

[1]Charles Robb, "On the Petroleum Springs of Western Canada," *Canadian Jour. Sci.*, New Ser., No. 34 (July, 1861); also William Logan, *op. cit.*

[2]Charles Robb, *op. cit.*

The modifications which petroleum undergoes by exposure to air, are very interesting. Partly by volatilization and partly by oxidation it becomes less fluid, and eventually is changed to solid form. Thus near to Oil Creek in Enniskillen, the thickened oil forms two layers known....as gum beds, of a viscid tarry consistency, and covering together two or three acres, with a thickness varying from a few inches to two feet. At Petrolia, in the northern part of Enniskillen, in sinking a well near a natural oil spring, a bed of mineral pitch or asphaltum, similar to that just described, but more solid, was met with at a depth of ten feet in the clay, and reposing upon a layer of gravel of four feet. This bed of bitumen is from two to four inches in thickness, and is readily separable into thin layers, which are so soft as to be flexible, and show upon their surfaces the remains of leaves and insects, which had become imbedded in the bitumen during its slow accumulation and solidification. It is mingled with a considerable portion of earthy matter. This little deposit is instructive, as showing the probable manner in which certain beds of bituminous rocks may have been produced with the concurrence of previously formed sources of petroleum.

In some instances the hardened bitumen is found in the cavities of the bituminous rocks themselves. Thus, at Kincardine, a black, hard, brilliant form of mineral pitch occurs in small quantities in the fissures of the bituminous limestones above described; and at the quarries in Bertie already noticed, a peculiar change is observed in the bitumen of the corals which have been long exposed at the outcrop of the rock. It is converted into a black matter, which lines the cells; and it no longer repels water, like the oily corals from within. Benzole, which readily dissolves the bitumen from these, does not affect the black color of the weathered corals, in which the bitumen has evidently been converted into an insoluble modification, as is shown by the following observations. A fragment of a *Favosites* impregnated with this black matter, was crushed and treated with dilute muriatic acid, which removed the carbonate of lime, and left five per cent of a brownish-black residue. This, when exposed to heat, burned with flame, without melting, and left a voluminous, coherent, coaly residue, which gave a little ash. When treated with a large amount of boiling benzole, the residue gave up only 16.5 per cent of soluble bitumen; and the subsequent analysis of the insoluble portion afforded volatile matter 28.1, carbon 67.7, ash 4.2 = 100.00. From these results, it appears that the soluble and liquid bitumen of the corals had become in great degree replaced by an insoluble, infusible carbonaceous matter, the result of the slow oxydation of the petroleum. It is probable that a less advanced stage in the process would present the solid but soluble bitumens of Kincardine and Grand Manitoulin. A black, brilliant carbonaceous matter, apparently similar to that from Bertie, occurs at Cornwall, in the cells of a coral of the Trenton group, the *Columnaria alveolata*. It has not however as yet been chemically examined.

These observations serve to throw light upon the origin of a black combustible coal-like matter, which occurs in many places in the Quebec group, and has in different localities been mistaken for coal. It was first described by Vanuxem, in the Geology of New York, under the name of anthracite, as occurring in the Calciferous formation with crystals of bitter spar and quartz. It sometimes coats these crystals, or the walls of the cavities, and at other

times appears in the form of buttons or drops, evidently, according to Mr. Vanuxem, having been introduced into these cavities in a liquid state, and subsequently hardened in a layer above the crystals, showing, by its having conformed to them, that this coal-like matter was once in a plastic state. It is very pulverulent, brittle, of a shining black, and according to Vanuxem yielded but a small amount of ash, and 11.5 per cent of volatile matter, which he regarded as consisting of water. (Geology of New York, iii, 33.)

In the Quebec group in Canada, which is regarded as the equivalent of the Calciferous formation, this substance has been observed at Quebec, Orleans Island, Point Lévis, Sillery, St. Nicholas, Lotbinière, Drummondville, Acton, the vicinity of the Chatte River in Gaspé, and many other places. It fills veins and fissures in the limestones, shales, and sandstones, and even in the trap rocks which traverse these. Sometimes it is found in buttons or drops, as described by Vanuxem, forming botryoidal masses. At other times it lines fissures, and is seen, as at Drummondville and at Sillery, spread over a surface which had been previously encrusted with small crystals of calcite. The shrinking of the layer has here given rise to cracks, such as are sometimes seen in a coat of varnish. In other cases it fills fissures several inches in diameter; so that it has been mistaken for coal, and attempts have been made to work it at Quebec and elsewhere. The mineral is never, however, in true beds like coal, but is always confined to veins and fissures which cut the strata; showing its deposition to have been posterior to the formation of the rocks. Near to the camp, on the western portion of the island of Orleans, there is a considerable vein of it in the shales, from which several hundredweights might be easily obtained. At St. Flavien in Lotbinière there occurs, in the copper-bearing slates, a vein of it an inch or two in width. The walls of the vein are lined with quartz, and the coaly matter is itself cut by thin veins of quartz, of later formation. In another specimen from this locality, the vein is nearly filled with crystalline quartz, and the bituminous matter is in small almond-shaped masses in the center of the vein. At Acton it fills irregular cracks and fissures, and sometimes forms masses of several inches in diameter. This matter is of a shining black color, very brittle, breaking into irregular fragments with a conchoidal frac ure. It is easily pulverized, giving a very black powder, and flies to pieces when heated. It varies considerably in its chemical characters. The mineral from Acton is much harder than from the other localities mentioned. When heated to redness in a close vessel, it gives off a portion of water, but no inflammable gas or vapor, and loses 6.9 per cent of its weight; leaving a carbon which is difficult of combustion, and gives when incinerated 2.2 parts of ash. Like the specimens described by Vanuxem, it approaches to anthracite in its characters. That from the other localities examamined, gives off, when heated, a greater or less proportion of combustible vapor, which condenses in part into a tarry liquid. Carefully selected specimens yield after incineration only a few thousandths of ash, apparently due to accidental impurities. In a specimen from the Mountain Hill, Quebec, the volatile matter equalled 19.5 per cent; that from the Island of Orleans, 21.0; that of St. Flavien, 15.8; and from another locality, six miles from this, 24.5 per cent. The latter, when exposed to heat, swells up, and leaves a porous coke, the fragments adhering like a caking coal. The same thing is observed,

to a less extent, with the specimens from Orleans Island. These carbonaceous matters are insoluble in benzole, with the exception of that last mentioned, which appears to contain a small amount of soluble bitumen. The resemblance of this substance to the altered insoluble bitumen from the Devonian corals at Bertie, taken in connection with the evidences that it was once in a liquid state, are such that it can scarcely be doubted that the coaly matters of the Quebec group have resulted from the slow alteration of liquid bitumen in the fissures of the strata. This is the more probable as the magnesian limestones of the Quebec group at Point Levis are still distinctly bituminous.

The chert beds among the Upper Copper-bearing rocks of Lake Superior, which are supposed to be the equivalents of the Quebec group, contain small portions of a black anthracite matter, filling fissures, and apparently identical with the material just described (p. 68). A carbonaceous matter, not unlike this, has been described by Durocher as occurring in Sweden, among crystalline rocks which are not improbably of the same age as those of the Quebec group.

As to the origin of bitumens, it has been by some supposed that they have had their origin in the action of heat on coal and similar organic matters, which by a slow distillation have yielded these oily matters, that have been condensed in the overlying strata. To this is to be objected the fact that bitumens occur in rocks in which there is no evidence of the action of heat; and moreover, that, from the distribution of the bitumen, as at Bertie, it is clear that it has not been brought into its present position by distillation, but has been generated in the porous beds where it is now found. This conclusion is in accordance with that of Mr. Wall, from his researches in Trinidad. The bitumen of that region, which belongs to the newer Tertiary rocks, and is associated with beds of lignite, is confined to particular strata which once contained vegetable remains. These, according to him, have undergone "a special mineralization, producing a bituminous matter instead of coal or lignite. This operation is not attributable to heat, nor of the nature of a distillation, but is due to chemical reactions at the ordinary temperature, and under the normal conditions of climate." (Proc. Geol. Society of London, May, 1860.)

In the paleozoic rocks of North America, the organic matter which has yielded the bitumen must be derived either from a marine vegetation, or from the remains of marine animals. These, especially the lower forms, differ but little in elementary composition from plants, and may as readily yield bitumen by their change. The transformation by which organic matters may be converted into bitumen, does not differ very greatly from that which produces the more bituminous coals, — to some of which, indeed, certain of the asphaltums approach very closely in composition. The true petroleums retain a larger proportion of hydrogen, and result from a change, under conditions as yet but imperfectly understood, by which a greater proportion of hydrogen is retained in combination. The diverse results of the fermentation of sugar under varying conditions, suggest analogies to the different transformations of vegetable and animal tissues which have resulted in the formation of lignite, coal, anthracite, asphaltum, and petroleum, together with carbonic acid and gaseous hydrocarbons as accessory products.

While a vegetable origin is assigned to the bitumen of more recent geological formations, it is probable that, although a marine vegetation may have

in some degree contributed to the formation of the bitumen of the paleozoic strata, an accumulation of molluscous animals in certain strata may have given rise, by a sub-aqueous decomposition, to the petroleum which is now found in these rocks. The small amount of organic matter which the corals contain would, in itself, be altogether inadequate to the production of the quantity of oil which is found associated with them; so that other organic bodies which have left no solid skeletons must have furnished by far the greater part of the petroleum of these paleozoic limestones.

The light carburetted hydrogen or marsh-gas, which is so often a product of the transformation of organic matters at ordinary temperatures, is abundant in the paleozoic rocks of Canada, and issues from many mineral springs. Those of Caledonia, Varennes, and Caxton, in the Lower Silurian series, give off great volumes of this gas, which keep the waters in constant agitation. Many other less important instances of the same kind might be mentioned; while in the higher strata of Western Canada, this gas is still more abundant, as at the well-known burning-spring near Niagara Falls, and in the region of the oil wells. In boring these, reservoirs of it are frequently penetrated, from which the gas is liberated with explosive violence. In nearly all the oil wells there is a greater or less disengagement of inflammable gas; so that it would appear that the strata almost everywhere in that region hold, in a condensed state, portions of light carburetted hydrogen, which is discharged wherever a natural fissure or an artificial boring furnishes a vent.

With regard to the petroleum obtained from the wells in the western peninsula, a notion has obtained some currency that its source is to be found in the Hamilton shales, and the presence, both at the summit and the base of this formation, of pyroschists, or so-called bituminous shales, has been thought to explain the origin of the oil. It should however be borne in mind that these brown or black hydrocarbonaceous shales are wrongly named bituminous. Although they burn with flame, and like coal, peat, and even wood, may be made to yield oily hydrocarbons by destructive distillation, they in most cases contain no petroleum, in which respect they are unlike the conglomerate sandrock (21) described by Mr. Lesley (page 240), and unlike the Trenton and Corniferous limestones which in many cases are permeated with oil, holding it in their pores, and in the cavities of the fossils which they contain. Numerous examples of the oil-bearing character of the Corniferous limestone might be cited from the Geology of Canada (page 378), where they are described in detail. Oil may be observed in the pores of this rock, at Horn's quarry in Bertie, at Gravelly Bay in Wainfleet, in Rainham, at Woodstock, near the village of Jarvis, and at Amherstburgh. The same characters are presented by this limestone in Ohio. The outcrops of this formation are not favorable for the accumulation of large quantities of oil, since denudation has there given opportunity for its escape, while the soft shales and marls of the Hamilton formation, which overlie it in other portions of the province, have allowed its preservation. The existence of oil-wells, sunk directly in this limestone, at Tilsonburg, and at Belle River, is, however, conclusive as to the source of the oil; and both at Thamesville and in various wells in Enniskillen, productive oil-veins have been found after sinking into the limestone underlying the Hamilton shales, as in the case of the well in Kentucky noticed on page 241.

It must not be understood from this that petroleum is not, to a small extent, indigenous in portions of the Hamilton group. The harder calcareous beds of this resemble lithologically the Corniferous limestone, and, like it, contain ready formed petroleum, as I have observed in Adelaide (page 242). Moreover, small portions of petroleum have been, by Prof. Hall, observed in calcareous concretions, both at the top and bottom of the Hamilton group in New York. Oil from such sources, however rare, may accumulate in the fissures which occur in these strata; which also serve as reservoirs for the oil rising from the underlying Corniferous limestone. In either case, however, whether indigenous in the one or the other group of strata, its formation is in no way dependent on the pyroschists of the Hamilton group, which have never been subjected to heat, and have lost none of their hydrocarbonaceous material. That petroleum has been generated in the calcareous strata, independent of coal, black shale, or similar matters, is shown, moreover, by its occurrence at Manitoulin (and elsewhere) in Lower Silurian limestones, which there form the base of the fossiliferous series, having only the barren Chazy sandstone between them and the ancient crystalline rocks.

After reading the conclusions of Hunt, which are, presumably, those of the New York and Ohio geologists, one can not help being impressed with the fact that present day geologists have not progressed so very much in comparison with the conclusions these men reached when the industry was a year or two old; for example, Hunt in the 1863-66 report, pages 260-61, speaking of the probability of finding oil in Gaspé peninsula, states:

As regards the probable future of such enterprise in Gaspé, it has already been shown in the preceding pages that the existence, in any oil-bearing region, of available sources of petroleum, depends upon a combination of many circumstances: (1) the proper attitude of the strata, (2) the existence of suitable fissures, which may act as reservoirs, and (3) such an impermeability of the surrounding and overlying strata as will prevent the outflowing and wasting of the accumulated oil. Of these conditions, we find, in the oil-bearing rocks of Gaspé, numerous undulations, causing anticlinals or axes of elevations, and along such lines the usual fissures and openings are doubtless not wanting. The numerous oil springs met with at the surface of the soil are so many evidences that these conditions have favored the accumulation of petroleum; but whether these springs are but the oozings from full reservoirs, ready to yield a copious supply to the skill of the laborer, as in many parts of the United States and Canada, or whether, as in other places, they are the last drainings from former accumulations, well nigh exhausted by the waste of ages, can only be determined by trial.

The failure of the few wells hitherto sunk in Gaspé should not be regarded as discouraging, for it has been found elsewhere that of two wells, one may strike a fissure or vein of oil at no great depth, while another well, near by, is unsuccessful, or only reaches the oil at a much greater depth; a fact due to the irregularity and obliquity of the fissures. As regards the site of natural oil-

springs, it should be considered that the petroleum may often pass some distance in a nearly horizontal direction beneath impermeable strata, and finally come to light at some distance to one side of the reservoir. The thickness of the sandstone in many parts of this region (where it attains 4,000 feet, and even 7,000 feet in its greatest development) is doubtless considerable, even on the crests of the anticlinals, and it may be necessary to sink deep wells along these lines before the presence or absence of available supplies of petroleum in this region can be ascertained.

It is to be remarked that in the thickness of the sandstone, which overlies the oil-bearing limestone of Gaspé, there is a resemblance to the conditions existing in western Pennsylvania, where the productive oil wells are sunk in a somewhat similar formation of sandstones and shales, of great thickness, which there overlies the Corniferous limestone, and, as we have endeavored to show, has been favorable to the accumulation and preservation of the petroleum derived from this lower formation. The Devonian sandstone in Gaspé covers a large tract of country, extending as far west as the Matapedia River, and it is not improbable that petroleum may be met with in other parts of its distribution than those where its presence has already been detected.

Hunt made a special report on Gaspé in 1865, *Petroleum, Its Geological Relations Considered with Especial Reference to Its Occurrence in Gaspê,* in which he quoted extracts from all the earlier reports that are mentioned in this text. He repeated the only new material in the *Geological Survey of Canada Report of 1866*, quoted in the preceding paragraphs. The map and geology of the district showing the anticlines are evidently the result of Logan's (1844), Murray's (1845), Richardson's (1857), and Bell's (1862) explorations, which were used in making the *Geological Map of Canada*, dated 1866, and *Geology of Canada, 1863.*

Hunt's understanding of the importance of gas should not be forgotten. On page 259 of the *Report of 1863-66*, Hunt says:

The presence of this gas imprisoned in the strata often plays an important part in oil wells, since, by its elasticity, it exerts a pressure which forces the oil from the fissures where this has accumulated and which may be supposed to be, in part, filled with gas.

Hunt also notes, on page 254 of the 1863-66 report, that the oil in the "Corniferous" could not have come from the Portage and Chemung Black shales (Murray suggested this in his *Report of 1855*) and gives his views on the theory of the distillation by heat, now not considered necessary. What he hints at is important—that the black shales are separated from the limestone by 180 feet of barren gray Hamilton shales, through which there is no evidence that oil has ever passed. He suggests that any oil in these gray shales has arisen from the limestone below.

One can scarcely refrain from speculating, or filling in between the lines, what happened in Canada after Drake's well was drilled. Logan, Murray, and Hunt were familiar with oil seeps. Logan had commented on the seeps along the Gaspé anticlines in 1844. Murray had, in 1854, concluded that the oil springs of western Ontario had their origin in bituminous shales. Hunt had experimented with the "gum beds" of Black Creek, and finally visited them, probably in 1860. No doubt his visit was a direct result of the excitement following Drake's discovery. In any case, Hunt was thoroughly acquainted with the causes of oil accumulation and how to expound them, because he gave his Montreal lecture previous to March 1, 1861.

The anticlinal theory was waiting for a geologist with an engineering "turn of mind" to build up a "structure contour map," and at the beginning of the sixties there were several men in Canada and the United States capable of doing it. Who the first one was can not be discovered at this date; the greatest thinkers are not the most gifted speakers or writers. However, anyone reading Logan's 1863 Report and Hunt's 1863-66 report can not fail to grasp the fact that there was no little discussion as to who was first to propound his own explanation of the accumulations of oil.

With regard to the actual anticlinal theory, the words of Logan, or Hunt, or both, are as follows. The quotation is from page 379 of the 1863 report.

> The petroleum springs which rise from this formation in Tilsonburgh, probably have their origin in such bituminous beds; and other springs of the same character, which issue in Enniskillen from strata above the Corniferous, very probably ascend, through these newer rocks, from the same formation. Some of these springs appear to be on the line of the great anticlinal, which runs through the western peninsula; and subordinate undulations of a similar character will be found connected with others. The oil, being lighter than water, and permeating with it the strata, naturally rises to the highest part, which is the crown of the anticlinal; whence it escapes to the surface by some of those cracks which are usually found in such positions. These petroleum springs, by the aid of wells and artificial borings, have been found to yield a very large supply; and the uses of the oil having been greatly extended by recently discovered modes of refining it, a new industry, to be noticed in a separate chapter, has arisen in Western Canada and other places where petroleum springs occur.
>
> It will be observed that the positions of these anticlinal forms in Western Canada thus become a matter of economic importance. The general course of the main anticlinal can be readily traced by means of the distribution of the formations. It would appear that the crown of the arch runs in a gentle curve, from the western extremity of Lake Ontario, by Woodstock; in the neighbor-

hood of which, the base of the Corniferous formation folds over it. Proceeding thence by the Thames, in the general bearing of the Great Western Railway, it would reach the town of Chatham, and then pass to Pigeon Bay on Lake Erie. The springs of Enniskillen would appear to be north of this axis, and they may probably be on a subordinate one parallel with it; which may be connected with the undulation that has already been mentioned as affecting the outcrop of the Guelph formation at Rockwood.

This is a very accurate description of the course of the Cincinnati anticline through Ontario. Hunt agains refers to this main anticlinal and the superimposed structures as follows. The quotation is the last paragraph of page 255 and parts of pages 256-58 of the *Report of 1863-66.*

A few remarks may here be permitted with regard to the distribution of petroleum wells over regions underlain by oil-bearing rocks. In the first place, it should be borne in mind that, judging from all analogies, this substance, or the matter from which it has been derived, was not, from the first, equally distributed through the oil-bearing formations, but like deposits of coal, gypsum, salt, and other materials, of chemical or organic origin, was limited by natural causes, and doubtless developed in some areas in much greater abundance than in others. In the second place, there must be, either in the oil-bearing formation, or in those overlying it, fissures in which, by slow infiltration, the oil from the adjacent portions can have accumulated. Where such are absent there may still be a gradual flow of oil from porous strata, into the well, and this movement will be greatly accelerated by the use of the pump; but the copious supply, and the spontaneous streams of oil which characterise most of the Canadian and American wells are, as is well known, connected with fissures in the strata. Such fissures may, and doubtless do, occur in horizontal rocks, where they result from contraction, but in regions which have been subjected to plication, as along the lines of anticlinals, it is notorious that fissures and breaks generally occur along the crests of the folds; the depressions between these, on the contrary, from the lateral compression to which the strata are there subjected, being unfavorable to the production of such fissures.

From these very obvious considerations it follows that we should expect, in a somewhat disturbed district, to find the oil-wells, like mineral springs, along the anticlinals.

With regard to the geological structure of the southwestern peninsula of Canada, the great mass of superficial deposits which there covers the rocks, has rendered its minute study very difficult. Within the last two years, however, the numerous borings, chiefly in search of petroleum, which have been made in nearly every township west of the meridian of London, have furnished data, which show the existence of several subordinate anticlinal folds to the northwest of that of the Thames, which, as the continuation of the Cincinnati anticlinal, may be regarded as the main one of the great axis of elevation which divides the coal field of Pennsylvania from that of Michigan. The existence of these subordinate anticlinals has already been indicated in the Geology of Canada. As appears from the delineation of the rocks of this region on the geological map, the result of denudation operating on these undulations, as the strata rise to the northeastward, from the transverse north and south de-

pression which crosses the peninsula (Geol. Can. p. 363), is to give to the eastern outcrop of the upper black shales, which may be taken as the base of the Portage group, a deeply indented outline. Tongue-like projections of these shales, extending eastward, mark the synclinal depressions between the successive anticlinals. To the north of the Thames, along which, at Chatham, Thamesville and Bothwell, the black shales of the base of the Portage are wanting, there occurs a relatively broad geological depression, in which these higher rocks are met with, through parts of Sombra, Camden, Euphemia, Mosa and Brooke. They are, however, interrupted by an undulation, which at Smith's mills, in Euphemia, brings to the surface the fossiliferous limestones of the Hamilton. To the north of Oil Springs and Petrolia, another synclinal prolongation of the Portage group, from Moore, extends into northern Enniskillen and Warwick, and on the northern side of this, the Hamilton again appears, rising into hills in Bosanquet, to dip once more beneath the Portage beds at Kettle Point.

It is probable that another subordinate synclinal may be found to run between Oil Springs and Petrolia, but there are as yet no data to decide the point, and the depression in this narrow belt would not perhaps be sufficient to bring in the black shales between these two places. Along the Thames, besides the oil of Bothwell and of Thamesville, petroleum, though not in large quantities, has been obtained in numerous borings from Chatham to Aldborough. A well sunk near the outcrop of the Hamilton, at Smith's Mills, is also said to have yielded a few barrels of oil, and small quantities have been obtained in the borings along the northern anticlinal, in Bosanquet. It should be remarked, with regard to all these anticlinals, excepting that of the Thames, that the southwestward dip of the strata causes the Hamilton rocks to disappear in that direction beneath the overlying Portage, so that these anticlinals, unless they die out, must be sought for in that direction, beneath the black shales—in which position they may even yield productive wells. The borings hitherto sunk in the black shales of the synclinals have, however, proved failures, so far as oil is concerned. The above explanations of points obvious to geologists, may, nevertheless, be not without value to those interested in oil-wells, and who may be less familiar with geological structure.

Hunt had at this time studied the logs of wells located throughout an area of 500 or 600 square miles of forest-covered, gently rolling-to-flat country; he gives the logs of 58 wells, and refers to other groups of wells in the developed fields on pages 244-49 of his 1863-66 report. These logs are quoted to support his estimate of the thickness of the members of the Devonian. His reference to railway stations, and river and lake levels, in making comparisons of these logs, leads one to believe that his conclusions reached and stated on pages 257 and 258 were based on levels; however, as the area is flat (an elevated lake bottom), it should be unnecessary to use more than the elevations of the railway stations, rivers, and lakes. Hunt makes it clear[1] that he has accepted the surface of the

[1]*Report of 1866*, p. 257, 4th line from bottom.

rocks as a datum, and determined several structures by accepting the thickness of the Portage black shales as the depth of the syncline, presuming that it was level, and therefrom described dips ranging from 10 to 30 feet per mile. This is the first record in Canada of a detailed report on such an area, where the author indicates structure favorable to the accumulation of oil.

Reference has already been made by Howell to the report of Henry Y. Hind on petroleum indications at Cheverie, Hants County, Nova Scotia, in 1871. This report needs no further discussion.

Thanks are due to W. F. Ferrier of Toronto, who, in his student days, worked with T. Sterry Hunt, and who, through his long life, has collected scientific books and reports of both Canada and the United States. His knowledge, advice, and reference library have been available to the writer and have furnished authentic information when the writer despaired of obtaining it.

CHEMICAL CONSIDERATIONS REGARDING ORIGIN OF PETROLEUM[1]

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ABSTRACT

Recent chemical work throwing light on the geochemistry of petroleum is reviewed. Evidence is submitted that many different sedimentary rocks are capable of causing polymerization of unsaturated hydrocarbons, a property hitherto generally believed to be limited to fuller's earth. Evidence strongly against the Engler theory of heat decomposition of fatty acids or other organic material is presented, including the recent work of Stadnikoff on peat and sapropelites. Hydrogenation under natural conditions or reduction by anaerobic fermentation processes, coupled with polymerization, are considered to be the major processes involved.

As the formation of petroleum in nature involves geology, chemistry, physics, and biology, it is not surprising that widely divergent theories should have arisen in regard to the matter. The continuing accumulation of facts, however, makes it possible to narrow the field of probabilities and in the following discussion no attempt is made to discuss the less plausible ideas. Natural gas must, of course, be included, because oil has never been found entirely free from gasoline hydrocarbons, barring the small quantities evolved in peat bogs and in some coal seams.

The present discussion is prompted by this accumulation of fact material and particularly by the persistence of the theory that petroleum has been formed by the action of heat on fatty acids or other organic material, a theory for which there is no geological evidence and very little chemical evidence, and against which there are weighty geological and chemical objections.

In its common form the theory is stated as a *distillation* process, probably because Engler (the original proponent) distilled fatty acids under moderate pressures and obtained a hydrocarbon distillate, bearing very little resemblance to any known petroleum, as will be more fully explained. More recently it has been attempted to fit catalytic hydrogenation into the story of petroleum formation, and S. C. Lind has pointed

[1]Read before the Association at the San Antonio meeting, March 20, 1931. Manuscript received, March 3, 1931.

[2]50 East Forty-first Street. Introduced by Max W. Ball.

out, though with caution, certain analogies between petroleums and the mixture of liquid hydrocarbons which he has obtained by the action of alpha rays on gaseous hydrocarbons. The accumulation of chemical and geological facts points decisively away from all of these theories and emphasizes the rationality and need of considering more carefully natural, or, more particularly, chemical and biological processes as performed by nature.

Professor Illing, in discussing a recent paper by Clark(1)[1] on the origin of petroleum, stated that geological evidence

> demands a theory of oil origin pene-contemporaneous with the sediments and not, as the distillation theory would suppose, as a later process of metamorphism.

H. Beeby Thompson(2) also states:

> In seeking the origin of petroleum one must not introduce extraordinary theories for its occasional occurrence amongst unusual surroundings, but consider only such views as will account for its extensive production and wide distribution by common processes of nature.

HEAT DECOMPOSITION THEORY

Engler(3) distilled fatty acids under pressure at 320°-400° C. (590°-752° F.) and obtained a distillate consisting of saturated and unsaturated hydrocarbons. The gasoline fraction contained 37 per cent unsaturated (olefinic) hydrocarbons. The expression "distillation" often heard in discussions of Engler's theory is inexcusable and unnecessary, as Engler himself pointed out; moreover, distillation is clearly impossible under the pressures existing at depths where temperatures even approaching those necessary for decomposition may, remotely, be possible.

The chemical objections to Engler's theory are chiefly that his product was highly unsaturated (olefinic) and contained only traces of aromatic or benzenoid hydrocarbons and no appreciable per cent of naphthenic or cyclic hydrocarbons. The gas from such decompositions, as shown by later work, contains unsaturated hydrocarbons and 2-6 per cent of carbon monoxide. Engler assumed that the unsaturated hydrocarbons would be polymerized to high-boiling cyclic hydrocarbons, a process very probable in the light of new facts given below, provided the initial material were formed according to Engler. As recently pointed out by Stadnikoff(4), this theory can not explain the formation of the naphthenic type of oils, nor those rich in aromatic hydrocarbons. To obtain oils rich in aromatic hydrocarbons from fatty acids would require the liberation of *hydrogen* and probably the formation of a car-

[1] Numbers in parentheses refer to list of references at the end.

bonaceous residue. No sedimentary or possible source rock has ever been found containing carbon residue or any other evidence of heat effect, and no natural gas has ever been shown to contain even a trace of hydrogen or carbon monoxide.

Engler called the initial product of heat decomposition, containing unsaturated hydrocarbons, "proto-petroleum." Nevertheless, in all the several hundred petroleums which have been examined, including those from most recent geological horizons, such as the Pliocene of the Los Angeles basin, there has not been an authenticated discovery of an oil containing olefinic hydrocarbons; and no recent sediment has yielded such a material. If the decomposition by heat occurs very slowly, as is assumed by many, at the gradually increasing temperatures noted at increasing depth of the deposits, some field in the whole range of depths and geologic periods should show oil in this transition stage. Some of our most prolific fields are those whose producing sands are of recent geologic periods, at very shallow depths, whose present maximum temperature, as shown by K. C. Heald (5), is 100° F., or lower, and whose strata are only slightly arched. Folding of strata, slips, and faulting have been advanced to account for the generation of the requisite heat. However, many fields are very little disturbed. The low anticline is the rule in many fields, and these changes, even faulting, are generally believed to occur through long periods of time, allowing ample time for such heat as the mathematicians may calculate, to be dissipated without great increase in temperature.

It should be noted, also, that the kerogen in oil shale is appreciably decomposed at 250° C. (482° F.); and although oil shales have been noticed which have been subjected to extreme folding and thrust pressures, no evidence whatever of thermal decomposition has been observed.

Other objections to Engler's theory are found in the composition of various petroleums. As already noted, Engler's distillates contained no appreciable amount of the cyclic or naphthenic hydrocarbons. Yet certain Californian and Russian oils yield light distillates (gasolines) consisting predominantly of such hydrocarbons. Engler suggested that the low-boiling (gasoline) olefines may be changed by polymerization to high-boiling naphthenes (lubricating oils), but the low-boiling naphthenes, cyclopentanes, and cyclohexanes predominating in gasolines from some crudes, can not possibly be explained in this way.[1] Also, the

[1]The recent experiments of Petroff, *Ber. d. deutschen chem. Ges.*, Vol. 63 (1930), p. 75, are not at all conclusive on this point; Petroff heated myristic and linoleic acids with clay and steam at 400° C. and 170 atmosphere pressure, but isolated no low-boiling naphthenes.

absence of aromatic hydrocarbons in Engler's products is significant. All petroleums which have been carefully examined, including even the light paraffine type (Pennsylvania), show aromatic, or benzenoid, hydrocarbons in the gasoline distillates, and the percentage increases in the higher-boiling distillates. In exceptional oils (Java), the content of aromatic hydrocarbons is 20 per cent or more. In the light distillates from Burmah petroleum, Carpenter (6) found 11-12 per cent of benzol and toluene, and in the kerosene fraction he found 20 per cent of aromatics, most of which were identified as xylenes, cymene, pseudo-cymene and mesitylene. A commercial American kerosene examined by Carpenter contained 11 per cent of aromatic hydrocarbons. Kerosene from certain California crudes contains aromatic hydrocarbons in such a large percentage that the liquid sulphur dioxide method of removing them is advantageously applied in refining these oils. If these oils, rich in aromatic hydrocarbons, had been formed by the heat decomposition of fatty acids, the hydrogen produced in their formation should be found in the associated natural gas, which is not the fact.

Paraffine wax was a minor constituent of Engler's distillates, although many oils of the naphthenic type contain no paraffine wax. Wax is found as a product of the heat decomposition of kerogen (in shale oil).

From the standpoint of heat decomposition the generation, in this way, of methane requires the formation of an equivalent amount of unsaturated, or olefinic, hydrocarbons. H. A. Wilson (7) has pointed out that in both the paraffine and olefine series the change from one or a few hydrocarbons to many hydrocarbons of the same series involves no great amount of reaction heat. If a sufficient *degree* of heat is postulated, the *great complexity of petroleum oils* can be readily explained, although it would perhaps be difficult to explain the great difference in composition shown by different petroleums. A. W. Francis (8) has also treated this subject from the thermodynamic standpoint and states that the formation of aromatic hydrocarbons requires temperatures within the range of 550°-900° C. This, however, seemingly assumes the splitting off of hydrogen. Another explanation of the formation of aromatic hydrocarbons is suggested in the following.

A whole series of objections to the Engler theory of petroleum origin is encountered if we examine the heat decomposition products of other fossil organic material, for example, peat, lignite, coal, oil shale, and resins. The products obtained by so-called low temperature distillation particularly are widely different from all petroleums. Thus the heat de-

composition (dry distillation) of peat and lignite yield a tarry oil containing 20-50 per cent phenols, a class of products totally absent in petroleum oils.

The condition and nature of the organic compounds of sulphur and nitrogen in petroleum also indicate a low-temperature history. Their presence does not necessarily lend weight to objections to the Engler theory. Fatty acids of themselves yield oils quite free from both sulphur and nitrogen derivatives. Hydrocarbons react with free sulphur to form hydrogen sulphide at moderate temperatures, and sulphur adds directly to olefinic hydrocarbons still more readily, but neither reaction forms the type of sulphur compounds, chiefly mercaptans and thioethers, found in petroleum. Heat decomposition of a wide variety of organic materials containing sulphur yields products containing much of this sulphur in the form of thiophenes (9), a type of sulphur derivative found in light oils produced by cracking, but seldom if ever occurring in natural petroleums. The nitrogen bases found in certain petroleum distillates, in very small proportions, have thus far been very little investigated, but those found in the lighter distillates of California oils are of a type not found in the products of the heat decomposition of coal or other organic nitrogenous material. Though sulphur derivatives could conceivably be formed by the reaction of hydrocarbons with sulphur, a similar formation of nitrogen compounds is for chemical reasons clearly impossible. It is much more reasonable, therefore, that both sulphur and nitrogen compounds in petroleum may be traced to the original organic material from which the oil was derived, indicating a low-temperature history.

CATALYTIC HYDROGENATION

Since the advent of commercial catalytic hydrogenation of oil, it has been suggested that this process or a similar process may occur in nature. The chief difficulty is again hydrogen, no trace of free hydrogen having been found in natural gas associated with petroleum of any age.

It should also be noted that one of the results of the industrial hydrogenation process is the almost complete removal of sulphur (as H_2S) and nitrogen from the oil treated. In this connection, the synthesis of hydrocarbon mixtures, a series of saturated paraffines, by the catalytic reduction of carbon monoxide by hydrogen, should be mentioned. The conditions of the synthesis (10), as well as the complete absence of carbon monoxide and hydrogen from all natural gases of all ages, seem sufficient to rule this out of serious consideration as one of nature's processes.

I. W. Beall (11) has suggested that hydrogenation, in a manner similar to the Bergius process, proceeds in nature and that the geologically older oils are the lightest, or rather are more completely hydrogenated. This is by no means the rule, however; for example, the oil from the Trenton limestone in the Ohio-Indiana field is heavier and contains much more sulphur than the more recently deposited paraffinic and nearly sulphur-free Pennsylvania oils. The purification of certain oils and the exceptionally light crudes of widely different geological age are more reasonably explained as the effect of filtration through partially absorbent strata, as suggested by Day (12).

It should be mentioned that the widespread occurrence of aromatic hydrocarbons in petroleums is not evidence against hydrogenation, since Hoffmann and Lang (13) have shown that, under the conditions of hydrogenation in the Bergius process, benzol and toluene are not changed.

OIL FORMATION FROM METHANE BY ALPHA RADIATION

S. C. Lind (14) has shown that the action of alpha rays on gaseous hydrocarbons results in the formation of a complex mixture of liquid hydrocarbons, and mentions that the rocks of the earth's crust are universally radioactive, though only in very low intensity. Lind and Bardwell cited one serious objection to such a theory of petroleum origin; that is, the fact that the action of alpha rays on all members of the paraffine and olefine series results in the liberation of much hydrogen. It should also be mentioned that if alpha radiation from radioactive minerals has had anything to do with oil formation, the natural gas associated with oil should be the richest in helium, as well as hydrogen. As already noted, hydrogen is always absent and the absolutely non-reactive element, helium, is found in highest percentage in the comparatively dry gases of so-called dry gas fields. Helium is by no means a universal constituent of natural gas, many gases containing no detectable quantity. Lind also mentions that the gases which do contain helium contain no hydrogen. In a private communication, Lind states that he is unable to see any way of taking care of this hydrogen and helium difficulty.

The alpha radiation theory is subject to the same fatal objections which were raised many years ago against the inorganic or carbide theory, that is, the composition of petroleum, the presence of optical active substances, the nearly universal presence of sulphur and nitrogen derivatives, as well as the ordinarily close geological association of petroleum with strata rich in fossils.

BIOCHEMICAL PROCESSES

Organic chemistry has furnished us with a wide variety of methods for building up paraffine hydrocarbons, and nearly every one of them has been proposed, at one time or another, to account for the formation of petroleum. The more we learn regarding the composition and manner of occurrence of petroleum, the more certain does it seem that the original material was of organic nature. But both the nature of this original raw material and the processes of its conversion are still obscure. It is hoped that the serious objection to the heat decomposition theory will be sufficient to direct attention to a study of *low-temperature biochemical and purely chemical changes*. The too ready assumption of heat decomposition conditions in petroliferous sediments, including even the recent shallow deposits, has led to all sorts of error and it becomes ever more difficult to force the facts into place to fit this old persistent theory.

The rational method of studying organic products formed in nature is to study natural biochemical processes, and not to apply synthetic processes of the laboratory or the temperatures of a volcano to these quiescent old sands and shales.

FORMATION OF HYDROCARBONS IN NATURE

It should be pointed out first that both saturated and unsaturated hydrocarbons in great variety are formed in nature, in both plants and animals, but particularly in the former. Many different crystalline paraffine waxes are found in the essential oils, and the well-known Bulgarian oil of roses contains so much paraffine wax that it is commonly semi-solid, resembling in this respect a wax distillate. The well known work on essential oils by E. Gildemeister (15) lists solid paraffine waxes as occurring in the essential oils of twenty-five plant species. What is the chemical mechanism of the formation of paraffine wax in the rose, at the temperature of a June afternoon? Certainly it is not heat decomposition or pressure distillation, or the Bergius process of hydrogenation, or alpha radiation of methane, or the result of somebody's mathematical equation.

The normal heptane which, together with synthetic iso-octane, is now used as a standard reference rule in measuring engine knock, is produced by two western pines, *Pinus sabiniana* and *Pinus jeffreyi* and also by *Pittosporum resiniferum* (a small prune-like fruit in the Philippine Islands). Nobody has yet proposed a theory as to how these paraffine hydrocarbons are formed in nature, or from what.

The unsaturated hydrocarbons are much more common in nature. The most important class industrially are those hydrocarbons constituting the various natural rubbers. Another large class are the terpenes, $C_{10}H_{16}$, and the sesquiterpenes, $C_{15}H_{24}$, which are widely distributed through many hundreds of plant species, including the conifers, some of which yield our commercial turpentines.

There has been a sufficient accumulation of fact about the terpenes, through study of associated substances and knowledge of their chemistry, to make it seem almost certain that the terpene hydrocarbons are formed by the decomposition of the terpene alcohols, under certain conditions in the living plant, that is, at *ordinary atmospheric temperatures*. In the whole terpene group and probably in the rubbers also, the primary chemical unit is a group containing five carbon atoms, and this group is regarded, by those who have studied the matter at all, as being related to the pentoses or pentosans of the plant, being formed from these substances by *reduction*. Certainly, whatever the exact mechanism, all of these hydrocarbons formed in plants can only be the result of a biochemical reduction, or, in other words, a hydrogenation process, at ordinary temperatures.

The mention of these facts is not for the purpose of suggesting that petroleum may be formed by an accumulation of any such hydrocarbons, but to emphasize the fact that natural biochemical processes, at ordinary temperatures, are capable of producing hydrocarbons by reduction or hydrogenation of other materials.

In animal forms of life, the formation of hydrocarbons seems to be very rare, perhaps because of the general strongly aerobic condition necessary for animal life. An exception is the highly unsaturated hydrocarbon, squalene, found in some shark-liver oils.

It is not at all necessary to assume that a high energy input is essential to accomplish such reductions. Such results are observed to occur with very little net energy change by the conversion of part of the original material to an oxidized condition and part to a reduction product, probably the best known illustration being the conversion of sugar or glucose to carbon dioxide and ethyl alcohol.

$$C_6H_{12}O_6 \rightarrow 2CO_2 + C_2H_5OH$$

The well known bacterial fermentation of cellulose to *methane*, carbon dioxide, and small proportions of other products is another illustration.

FORMATION OF AROMATIC HYDROCARBONS AT LOW TEMPERATURES

The presence of substantial proportions of aromatic hydrocarbon in petroleum, amounting to as much as 20 per cent of the gasoline fraction in certain oils, and the seemingly universal occurrence of small amounts of these benzenoid hydrocarbons in petroleums, is very puzzling in view of the evidence against thermal decomposition. The pressure distillation decompositions at 400° C. did not yield benzene hydrocarbons, and even the high-temperature vapor-phase cracking at 590°-650° C. (1,100°-1,200° F.) yields highly unsaturated products, but very little benzene or its derivatives. In fact, the higher the temperature employed in heat decomposition, the less do the products resemble petroleum. A. W. Francis (8) calculates that temperatures of 550° C. (1,022° F.), or higher, are necessary to form appreciable percentages of benzene from the paraffines.

The same principle, already mentioned in the simultaneous formation of oxidized and reduced products (paraffines) through biochemical agencies, at low temperatures, may also explain the formation of benzene hydrocarbons at much lower temperatures than any hitherto considered.

The type of reaction known as "disproportionation" and involving simultaneously a "step down" and a "step up" in energy change, the one reaction furnishing all or most of the energy for the other, was observed by Zelinsky (16) when certain terpenes are passed over metallic catalysts at about 190° C. Thus pinene and *beta* pinene are converted smoothly into cymene and dihydropinene.

$$2C_{10}H_{16} \rightarrow C_{10}H_{14}\ (\text{cymene}) + C_{10}H_{18}$$

The terpene thujene behaves in a similar manner. Limonene gives 66 percent cymene and 33 per cent methane, and simple cyclohexanes are converted into benzol and cyclohexane derivatives (17).

The writer has shown in recent unpublished work that fuller's earth is capable of causing reactions similar to those noted by Zelinsky with metallic catalysts. Thus, in addition to the well known polymerizing action of fuller's earth on turpentine or pinene, the principal products under some conditions are cymene and methane, together with some dipentene. When the vapors are passed through the fuller's earth, the latter reactions, rather than polymerization, are the chief result. This is particularly significant in view of the fact that a large number of sedimentary rocks of Oklahoma also show the properties

generally supposed to be characteristic of fuller's earth, to a greater or less degree.

As already noted, the large percentage of cyclic hydrocarbons, or naphthenes, are even more difficult to account for, by the heat decomposition theory, than are the benzene hydrocarbons. It will be remembered that no naphthenes were formed in Engler's experiments. It is now possible, as a result of recent work, to give the composition of many petroleums with respect to their content of paraffinic, naphthenic, and benzenoid hydrocarbons (Table I).

TABLE I

BENZENES, NAPHTHENES, AND PARAFFINES IN LIGHT DISTILLATES

Fraction Boiling Point °C.	BIBI EIBAT			MEXIA, TEX.			TONKAWA, OKLA.			DAVENPORT, OKLA.			HUNTINGTON BEACH, CALIF.		
	Per Cent Benzenes	*Naphthenes*	*Paraffines*	*Benzenes*	*Naphthenes*	*Paraffines*	*Benzenes*	*Naphthenes*	*Paraffines*	*Benzenes*	*Naphthenes*	*Paraffines*	*Benzenes*	*Naphthenes*	*Paraffines*
60–95	3	40	57	29	17	54	6	26	68	5	21	74	4	31	65
95–122	3	52	45	21	22	57	8	34	58	7	28	65	6	48	46
122–150	7	66	27	19	23	58	12	43	45	12	33	55	11	64	25
150–200	12	69	19	16	21	63	20	41	39	16	29	55	17	61	22
200–250	22	51	27	12	20	68	22	34	44	17	31	52	25	45	30
250–300	30	41	29	12	29	59	25	29	46	17	32	51	29	40	31

Most of the California oils are higher in naphthenes and lower in paraffines than the Huntington Beach crude. Ssachanoff and Wirabianz (18) have summarized their studies on the type composition of petroleums as shown in Table II.

TABLE II

AVERAGE COMPOSITION OF TYPICAL PETROLEUMS

Type of Crude	*Wax Per cent*	*Asphalt Per cent*	*Composition of 250°-300° C. Fraction*			*Specific Gravity of Residue over 300° C.*
			Paraffine	*Naphthene*	*Benzenes*	
Light paraffinic	1.5–10	0– 6	46–61	22–32	12–25	0.897–0.929
Paraffine-naphthene	1– 6	0– 6	42–45	38–39	16–20	0.897–0.908
Naphthenic	trace	0– 6	15–26	61–76	8–13	0.895–0.912
Benzenoid	0– 0.5	0–20	0– 8	57–78	20–35	0.950–0.970

The percentages of benzenes and naphthenes in the gasoline-kerosene distillates of the light paraffine crudes is particularly noteworthy and not in accord with our older ideas as to the composition of such crudes.

It should be observed also that the formation of benzenoid hydrocarbons by the high temperatures required to form them by heat decomposition is utterly incompatible with the retention of optical activity such as we find in petroleum distillates. P. I. Walden (19) states that the fact of the optical activity of petroleum oils is alone sufficient to prove their low-temperature history. Java petroleum, well known for its high content of benzene hydrocarbons, is relatively strongly laevorotatory (3).

POSSIBLE RAW MATERIALS FOR PETROLEUM FORMATION

The reason that there is still so much speculation as to the organic source and the method of formation of petroleum is that in spite of all the observation and study of recent deposits and concurrent depositions of various kinds, nothing has ever been observed which can certainly be regarded as petroleum in process of formation. Stadnikoff (4) has suggested that the preservation of petroleum requires that it be not formed until the material associated with it, or with the parent substance, is overlain and sealed from escape by an impervious layer. This is well borne out by the recent observations of P. D. Trask (20), who found no liquid hydrocarbons in a variety of recently deposited marine sediments. Fatty and oily substances constituted less than 1 per cent of the organic material present, as indicated by solvent extraction methods. The nature of the organic material in these sediments was not shown.

Consistent with the conditions necessary for petroleum or gas preservation as stated by Stadnikoff, are the recent findings of E. McKenzie Taylor (21), who has shown that bacterial fermentation under permeable clay may be strongly aerobic, but that clay deposited in salt water later becomes alkaline and is then in a deflocculated and quite impermeable condition, permitting only strictly anaerobic fermentation beneath such a seal.

A brief summary of the possible types of organic raw material which may conceivably serve as raw material for petroleum is as follows.

1. *Proteins* are rapidly and almost completely destroyed in putrefaction. Small proportions are evidently preserved under anaerobic conditions, as indicated by the nitrogen and sulphur compounds in petroleum.

2. *Cellulose* (22) is rapidly destroyed by micro-organisms without the formation of humic acids or other resistant material, and readily gives methane under favorable anaerobic conditions.

3. *Lignins* are very resistant to micro-organisms, and are slowly converted to humus substances.

4. *Oleoresins* gradually lose their volatile oils, but retain their resinous character in fossilized condition through long periods of geologic time.

5. *Waxes* (23) are exceedingly resistant. Waxes in peat show no appreciable change with increasing age and waxes isolated from brown coal show no evidence of change.

6. *Fatty oils* are hydrolyzed in a few years in the presence of water to fatty acids. The great majority of fatty substances are oils at ordinary temperatures and are accordingly unsaturated. They are readily oxidized and polymerized.

As the waxes and resins persist as such in deposits of great age, the lignins form humic acids, and the proteins and cellulose rapidly are lost as gaseous or soluble decomposition products, we are compelled to turn to the fatty oils. Under aerobic conditions, such as exist in shallow water deposits, the unsaturated fatty oils might be expected to oxidize to solid amorphous products of uncertain structure such as linoxyn, to simpler fatty acids with splitting of the carbon chain, to lactones, et cetera. Stadnikoff (4) lays great stress on the polymerization of the unsaturated fatty acids. Both types of change may occur to form the solid or semisolid organic material, that is, the physical form necessary for its preservation until adequately sealed in by overlying deposits.

If this be the history, the parent substance of petroleums should be a soft amorphous solid material thinly disseminated through the geologically recent sediment. It is to be expected that further chemical study of geologically recent deposits will fill in the gaps in this history and that the transition from the fatty acids, losing their oily fatty acid character (probably rapidly) to form the non-extractable solid and the gradual conversion of this material, will be observed.

Accordingly, the parent substance or "proto-petroleum" should not be the highly unsaturated oil, resembling unrefined cracked gasoline, of Engler, but a type of solid material whose composition may be expected to vary widely according to age and the type of organism chiefly the cause of the formation of the original fatty material. It seems certain that the *coorongite*, studied particularly by R. Thiessen (23), is one example of such a material. Only the uncritical, stubborn re-

tention of old theories has obscured the significance of the observations of Thiessen.

The properties of this interesting material are of such importance that they are summarized as follows. Coorongite forms in a salt-water lagoon in southern Australia not far from Coorong. In this and nearly all other lagoons there is an abundant growth of a blue-green alga which Thiessen has named *Elaeophyton coorongiana*, because of the high content of fatty oil. Toward the end of winter the surface of the water in these localities becomes covered with a green scum which collects on the sandy shores and finally dries to a dark brown rough mass. From his field and laboratory observations, Thiessen regards the coorongite as having been formed from the fatty oil of the algae. One specimen yielded 70.0 per cent of a thick viscous yellow oil by extraction with carbon bisulphide. Another specimen, on extraction with this solvent, yielded only 24 per cent, which extract was a yellow wax, soft at 35° and melted at 42°, and which proved to be unsaponifiable. The organic material not extractable by carbon bisulphide was saponifiable and showed the composition $(C_{10}H_{18}O_3)_x$. In commenting on this, Stadnikoff states:

> It appears from these results that coorongite is a product resulting from two different changes in the fatty acids. One of these changes results in the oxidation and polymerization of the unsaturated fatty acid. This takes place due to access of air. The second type of change consists in the loss of the carboxyl, or acid group of the fatty acids, and their polymers under the conditions of anaerobic decomposition.

In a later investigation, Stadnikoff and Weizmann (24) obtained 57 per cent of an extracted oil, by benzene, which was separated into an unsaponifiable oil and 16 per cent of fatty acids.

The loss of CO_2 from the fatty acids is probably due to biochemical action, by micro-organisms, under very mild conditions of temperature. The presence of unsaponifiable material in recent sediments, the presence of paraffines in the essential oils of living plants, and the known biochemical utilization of the fatty acids in animal and plant organisms indicates that loss of CO_2 is easily accomplished in nature by biochemical methods.

There is nothing in the record of experimental work, however, which accounts satisfactorily for the break-up of the fatty acids to the hydrocarbons which are found in the lighter distillates, gasoline and kerosene. This whole problem is unsolved.

POLYMERIZING ACTION OF SEDIMENTARY ROCKS

As nearly all of the fatty acids found in nature contain only sixteen or eighteen carbon atoms, it is evident that the formation of all the gas oil and lubricant fractions can be derived from fatty acids only by polymerization (and loss of CO_2). Engler recognized this, and assumed the polymerization of his cracked distillates or "proto-petroleum."

Although the polymerization of olefines can generally be accomplished by heat and pressure, the existence of typical petroleums in shallow low-temperature sedimentary rocks and other evidence already noted, leads one naturally to suspect some other agency. To account for the facts, the polymerizing agent or influence must be universally associated with petroleum.

Fuller's earth has long been known for its polymerizing action on certain unsaturated hydrocarbons and has long been used in the refining industry for its absorptive and decolorizing properties. However, fuller's earth is found only in a few localities and has never been observed in close association with petroleum. The reasons for its valuable properties are quite obscure, but are generally believed to be due to its fine physical structure, and the presence in the earth of partly dehydrated free silicic acid has also been suggested as the cause of its action. If all the water in the mineral is expelled by heating to a high heat, the material is "dead burned" and loses its activity.

The foregoing considerations led the writer to examine several sedimentary rocks from Oklahoma, kindly sent by F. W. Padgett and Charles N. Gould, of the University of Oklahoma. Several minerals holding water in combination were also examined. The minerals were partly dehydrated by heating to about 300° C. and treated with two volumes of turpentine. Under these conditions a typical fuller's earth caused 75 per cent of the oil to be polymerized. The percentage of the polymer was found by extracting all the oil and distilling off the light oil, unpolymerized turpentine, and other light hydrocarbons, dipentene, cymene, and menthane. All of the Oklahoma sedimentary rocks examined showed marked polymerization and several of the shales were fully as effective as the fuller's earth in this respect.

The tests were made at room temperature, and those specimens causing energetic polymerization were cooled to prevent loss. Many more substances should be examined before hazarding any theory of this behavior, but the interesting fact is that all of these sedimentary rocks show very marked ability to cause polymerization. Thus, there is, in sedimentary rocks, including the fine sandstones, a material similar to

TABLE III

POLYMERIZING EFFECT OF OKLAHOMA SEDIMENTARY ROCKS AND SOME MINERALS ON TURPENTINE

Mineral	*Per Cent Polymer*
Fuller's earth of Georgia	75
Sylvan shale	76
Red-bed clay	65
Tertiary clays	68
Greensand, New Jersey	72
Greensand, Texas	70
Serpentine, Easton, Pa.	60
Gray Persian sandstone	56
Stanley shale	57
Regan sandstone	50
Calvin sandstone	46
Simpson sandstone	34
Permian sandstone	30
Bentonite	34
Bauxite, Georgia	58
Silica gel	23
Kaolin	12
"Glaucosil" (acid leached greensand)	45
Prehnite (zeolite)	None
Stilbite (zeolite)	None
Talc	None
Infusorial earth	None
Powdered pumice	None
Ferric oxide, pure	None
Aluminum oxide, pure	None

fuller's earth in its polymerizing action. In view of the inertness of the very fine siliceous material, infusorial earth, and the high activity of the shales, it may well be concluded that it is the small amount of clay material in the sandstones which is responsible for this action.

SUMMARY

All of the chemical and geological evidence indicates a low-temperature history of petroleum. There is no chemical or geological evidence of heat decomposition in accounting for the formation of petroleum.

The composition of petroleums and natural gas precludes the action of alpha radiation from radioactive minerals as an agent in petroleum formation.

High pressure hydrogenation as a factor in petroleum formation is precluded by the absence of hydrogen in natural gas of all ages, and other evidence.

The presence of benzene hydrocarbons in petroleum can be accounted for by disproportionation reactions at low temperatures.

The property of causing polymerization is shown to be possessed by widely different sedimentary rocks, and this is believed to account for the gas oil and lubricant fractions of petroleum.

There is no plausible explanation for the large number of hydrocarbons in petroleum, particularly in the lighter distillates.

If the processes involved in the formation of these complex mixtures require geologic cycles of time, experimental observation of petroleum formation is forever an impossibility; but, if this be the fact, it is certain that study of the chemical nature of the organic materials in sediments and deposits of different ages will reveal the methods of petroleum formation.

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DISCUSSION

PARKER D. TRASK, Princeton, New Jersey: If petroleum is generated by polymerization of hydrocarbons, it almost certainly must occur after the sediments have been consolidated, because chemical studies of large quantities of several different recent sediments having a large organic content indicate that they contain no measurable amount of liquid hydrocarbons.

Although it is probable that the temperatures required for the production of oil by distillation of organic matter exceed those at which oil generates underground, some of the work done by American Petroleum Institute Research Project 4 indicates that conversion of the organic matter to a form soluble in ether takes place at much lower temperatures than those required to generate oil by destructive distillation; consequently, it is not impossible that transformations of the organic matter, akin to distillation, may take place slowly at temperatures prevailing underground in the zone of petroleum formation.

PETROLEUM POSSIBILITIES OF TURKEY[1]

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ABSTRACT

The Republic of Turkey is divided into three parts for reasons of geography as well as convenience. The geology of a dozen localities is briefly discussed. Although most of these localities may be considered too remote or unfavorable geologically to produce oil in commercial quantities, the region bordering Iraq and Syria is recognized as potential territory. The petroleum laws of 1924 which have handicapped development are now in process of modification.

INTRODUCTION

The purpose of the writer is to present a brief outline of the geology of the regions which have petroleum possibilities, within the present boundaries of the Turkish Republic. Very little geological reconnaissance has been done in Turkey by modern oil geologists. The government conducted a preliminary and cursory examination in 1925. This work was done by M. Lucius, who was associated last year with the writer in part of the examination. Shirley L. Mason[3] subsequently visited some of the areas and presented his observations in a paper published in this *Bulletin*. During the World War, W. Schweer[4] examined the petroleum possibilities of Turkey, principally in Iraq and Persia. In these two countries considerable work has been done by the geologists of the Anglo-Persian Oil Company, Ltd., and Iraq Petroleum Company, Ltd., and some of their findings have been published recently.[5]

For present purposes the petroliferous provinces of Turkey are divided into three groups: (1) Mardin region, (2) Anatolian Plateau, and (3) Miscellaneous Coastal.

[1]Read before the Association at the San Antonio meeting, March 21, 1931.

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[3]Shirley L. Mason, "Geology of Prospective Oil Territory in Republic of Turkey," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14, No. 6 (June, 1930), pp. 687-704.

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FIG. 1.—Map of Republic of Turkey.

Before discussing these areas, it is desirable to mention that the present petroleum laws of the republic, enacted in 1924, which have been considered unfavorable to profitable investment, are being modified in a way that will make investment by foreign capital a worth-while undertaking.

Mardin Region

The Mardin region is in the southeastern part of Turkey and adjoins Persia, Iraq, and Syria. The town of Mardin is on a branch line of the former Bagdad Railway, which has its terminus at Nusaybin on the Syrian boundary. Most of the travel from Europe to Iraq and Persia is by the Simplon Express to Istanbul (Constantinople); thence by the Taurus Express to Nusaybin. Mardin and Nusaybin are 1,133 and 1,154 miles, respectively, from Constantinople and 475 and 496 miles from the seaport of Mersin on the Mediterranean Sea. The country west and south of the Tigris can be traversed with automobiles, though mules, horses, and camels are the principal means of transportation east of the Tigris and in the mountainous sections. Except in the Midyat area the water supply is plentiful. The people inhabiting the area are engaged in farming and cattle raising. They are intelligent and can be trained to perform the ordinary duties with a drilling rig, at an average wage of $1.00 per day. Though the principal cities, Mardin and Diarbekir, afford good hotel accommodations, a complete camping outfit must be carried for any geological investigation.

GEOGRAPHY

Drainage.—The Tigris is the main body of water in this region. It is not large at Diarbekir, which is not far from its source, but several large streams join it and within a short distance it assumes navigable size. Even with animals most of the crossings must be ferried.

Topography.—The Iranian ranges extend into Turkey north of Habur Su, but the northwest trend observed in Persia and Iraq gradually turns westward. The region is mountainous east and north of the Tigris. In the south the mountains are smaller, and the country is rolling and flat, merging into the desert plain. Mountains become progressively higher toward the east and north. For example, the first range east of the Tigris is the Judi Mountain 8,200 feet in elevation, where Noah's ark is believed to have landed. East of it Nehri Nar Dag, near Hizil Su, has an elevation of 9,500 feet, and farther east the Shahdinan and Abreza mountains attain elevations of 11,000 feet. Similarly, north of the Tigris the first mountains range from 4,600 to 5,200 feet in

FIG. 1.—Map of Republic of Turkey.

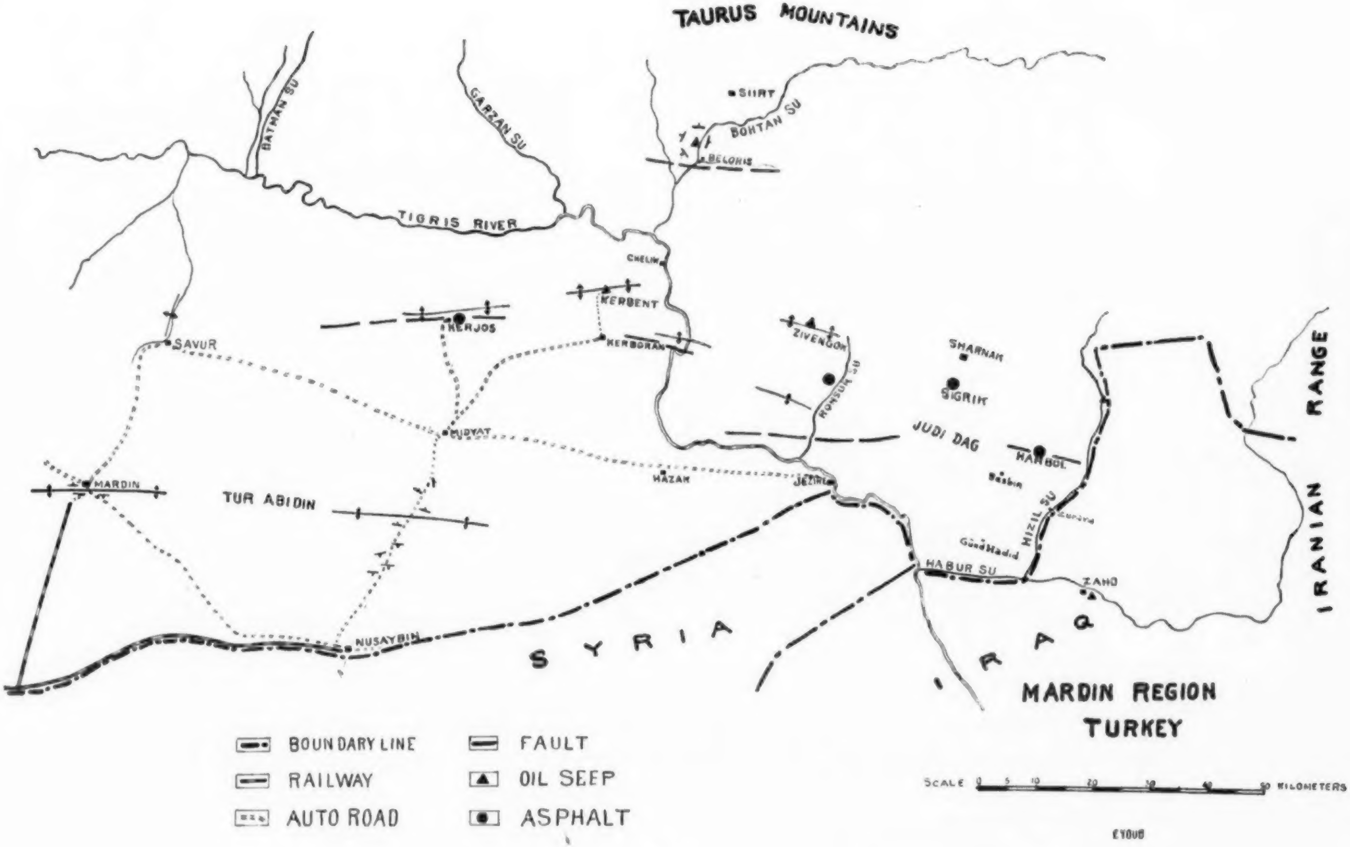

TAURUS MOUNTAINS
BATMAN SU
GARZAN SU
SIIRT
BOHTAN SU
BELORIS
TIGRIS RIVER
CHELIK
KERBENT
KERJOS
KERBORAN
ZIVENGOR
SHARNAK
SIGRIK
JUDI DAG
HARBOL
SAVUR
MIDYAT
MARDIN
TUR ABIDIN
HAZAK
JEZIRE
HIZIL SU
HABUR SU
ZAHO
NUSAYBIN
SYRIA
IRAQ
IRANIAN RANGE
MARDIN REGION
TURKEY
BOUNDARY LINE
RAILWAY
AUTO ROAD
FAULT
OIL SEEP
ASPHALT
SCALE 0 5 10 20 30 40 50 KILOMETERS

FIG. 2

elevation, but farther north, in the anti-Taurus range, one of the peaks, Maratu Dag, is more than 10,000 feet in elevation.

Climate.—The climate of the area is generally healthful. The hilly part is distinctly salubrious. Here it is common to observe several octogenarians in one small village. At Sharnak, a small community of 1,000 population, three claimed to be centenarians. Some malaria exists in the lowlands of Jezire and Nusaybin. The latter section is very hot during the summer months.

Maps.—The best topographic map is the one prepared by the Turkish military staff, but this is not available for commercial use. The maps prepared by the British general staff, on the scale of 1:250,000 with 100-foot contours, are those ordinarily used and may be obtained from E. Stanford, Ltd., London, at approximately $0.85 each. The map by Kiepert is recognized to be more accurate, but it is on the scale of 1:400,000. Only very small-scale geological maps may be obtained. A map prepared by the Turkish Government several years ago covers the whole republic on a scale of 1:2,000,000. Abiel's International map (scale 1:1,000,000) is hardly obtainable. Oswald's map (1:2,500,000) and Frech's (1:4,000,000) are too small to be of any help in ordinary field work.

STRATIGRAPHY

It should be remembered that considerable work must be done before more than a general idea of the stratigraphy of the region may be thoroughly understood. Although certain relationships are still to be explained, enough is known to present a general column.

Pleistocene and Recent.—The fluviatile deposits along the Tigris, composed of mud, silt, sand, and conglomerate, on two—in places three—terraces, constitute this group. The highest of these terraces, 100 meters above the level of the river, is Pleistocene.

In the vicinity of Jezire the Pleistocene deposits are the fluviatile conglomerates, poorly consolidated sandstones, basaltic lava flows with columnar structure, and pink sandy shales. The section on the right bank, 2 kilometers west of the town of Jezire, from top to bottom, is as follows.

	Thickness in Feet
Basaltic lava flows	150–250
Poorly consolidated sandstones	180–200
Pink sandy shales and shales	150

It is interesting to notice that the basaltic flows are exposed only on the right bank of the river. Basalt flows observed in the vicinity of Diarbekir are also referred to the Pleistocene.

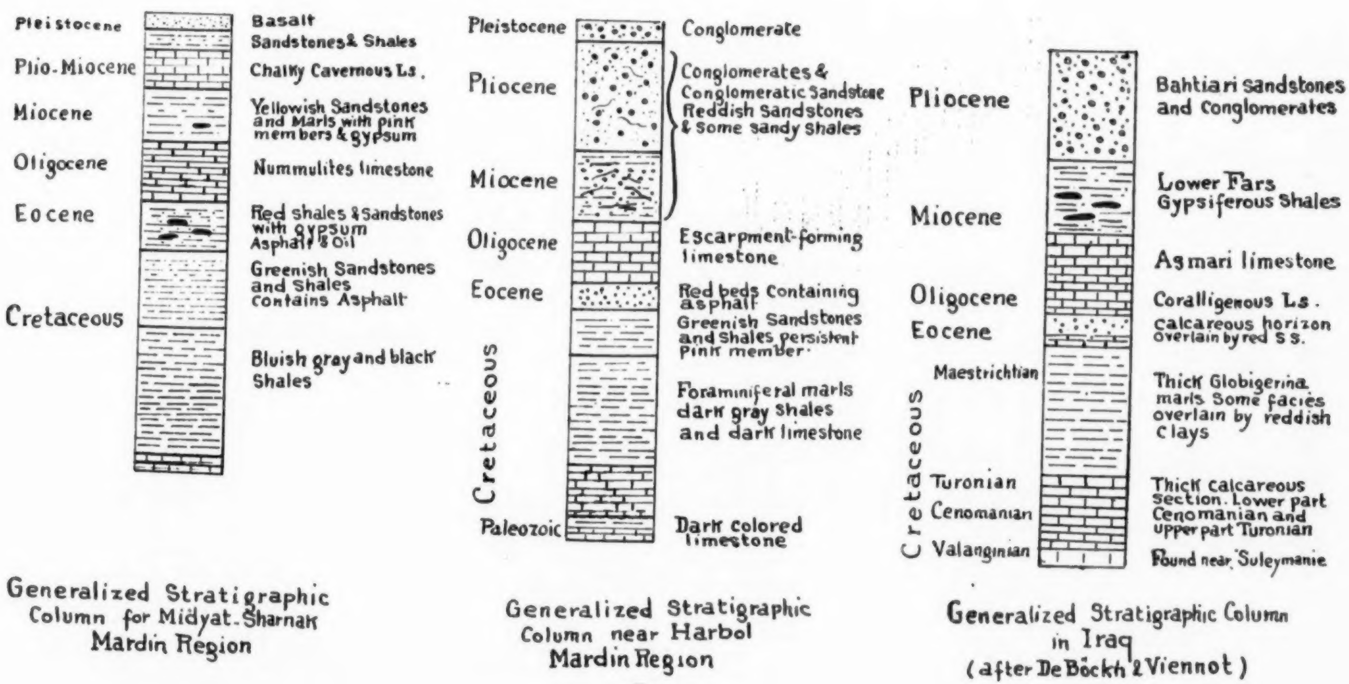

Pleistocene
Plio-Miocene
Miocene
Oligocene
Eocene
Cretaceous
Basalt
Sandstones & Shales
Chalky Cavernous Ls.
Yellowish Sandstones and Marls with pink members & gypsum
Nummulites limestone
Red shales & Sandstones with gypsum Asphalt & Oil
Greenish Sandstones and Shales Contains Asphalt
Bluish gray and black Shales
Generalized Stratigraphic Column for Midyat-Sharnak Mardin Region
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Cretaceous
Paleozoic
Conglomerate
Conglomerates & Conglomeratic Sandstone Reddish Sandstones & some sandy shales
Escarpment-forming limestone
Red beds containing asphalt
Greenish Sandstones and Shales persistent pink member.
Foraminiferal marls dark gray shales and dark limestone
Dark colored limestone
Generalized Stratigraphic Column near Harbol Mardin Region
Pliocene
Miocene
Oligocene
Eocene
Cretaceous
Maestrichtian
Turonian
Cenomanian
Valanginian
Bahtiari Sandstones and Conglomerates
Lower Fars Gypsiferous Shales
Asmari limestone
Coralligenous Ls.
Calcareous horizon overlain by red S S.
Thick Globigerina marls Some facies overlain by reddish clays
Thick calcareous section. Lower part Cenomanian and upper part Turonian
Found near Suleymanie
Generalized Stratigraphic Column in Iraq (after De Böckh & Viennot)

FIG. 3

Pliocene.—A very thick continental deposit composed principally of conglomerate, conglomeratic sandstone, and reddish sandstones is extensively developed in the Nahiye of Slopi immediately north of the Iraq border and Habor Su. The highest part of the section is entirely a lime-cemented conglomerate with medium-to-large boulders of older limestones making the matrix. Some of these are as large as 12 inches in diameter, but most of the pieces range from 1 inch to 3 inches. The middle and lower parts of the section contain red and gray sandstones, in places cross-bedded. A small creek between Zurava and Kitta exposes thin-bedded sandstones and shales with lignite. The Pliocene covers a large area and dips consistently toward the south. The dips range from 12° to 18°, but near Gir'reh Dag they steepen to 45°, 50°, and 55°. The thickness of the section is not less than 1,500 meters (5,000 feet) and probably not more than 2,500 meters (8,200 feet). It is possible that a series of dip faults makes the thickness seem greater than it is. The estimate of a thickness of 1,500-2,500 meters is given with this possibility in mind. The section is well developed between Besbin and Günd Hadid and along Hizil Su from Zurava up.

The upper part of these beds is believed to be correlated with the Kurd series of Richardson and the Bakhtiari of Persia. But the section near the base probably corresponds with the upper Fars.

Miocene.—Outside of the area where the thick continental deposits occur, the Miocene may be divided into an upper cavernous limestone and a lower series of pinkish shales and sandstones with gypsum.

On the right bank of the Tigris, grayish brown limestones are extensively developed, covering the hills from Mardin to Jezire and from Diarbekir to Siirt. The upper part of these limestones is distinctly chalky. They seem to be unfossiliferous except for the *Foraminifera.* The thickness of this limestone as seen in the region of Kerboran and along the road between Nusaybin and Midyat is estimated to be approximately 125 meters (410 feet). The exposures in the vicinity of Siirt, particularly along Bohtan Su, show a thickness of almost 200 meters (650 feet).

The pinkish shales underlying the limestone in the Siirt area contain great amounts of gypsum. The equivalent beds in the Kerboran region contain fauna that suggest an upper Miocene age. Near the town of Siirt several pits are dug in this horizon where gypsum is quarried. The base of the gypsiferous shales was not observed by the writer at the Siirt area, but more than 150 meters were exposed.

Oligocene.—The massive to well bedded escarpment-forming limestone, observed from Hizil Su on the Iraq frontier to Besbin, Judi Moun-

tains, and Kasyrik Gorge, with a profusion of *Oligopygus* and other small echinoid forms, is referred to the Oligocene and it probably corresponds with the Asmari of Persia. The section is well exposed at the Besbin Gorge. It is as follows.

	Thickness in Meters (and Feet)	
1. Light-colored chalky limestone	180	(590)
2. Bluish gray well bedded limestone	545	(1,780)
	725	(2,370)

Farther west at the Kasyrik Gorge the section is as follows.

1. Light-colored chalky limestone	165	(540)
2. Bluish gray, cherty, well bedded limestone	600	(1,960)
	765	(2,500)

Eocene.—Red sandstones and sandy shales with here and there a conglomerate member underlie the escarpment-forming limestone. No fossils have been found in this group, and there is no good reason to consider it Eocene except that it underlies the beds believed to be Oligocene and that the beds of similar appearance in the Mosul area have been called Eocene. The thickness of this formation at the Kasyrik Canyon, and at other localities where it has been observed, is from 200 to 250 meters. It is gypsiferous at places, as at the Zivengok section. The small quantity of gypsum that is found in the Harbol area is restricted to the immediate vicinity of the asphalt deposit and is secondary. At Zivengok, however, it is depositional. There is danger of confusing these gypsiferous shales as they appear at Zivengok, at Siirt, and at Kerbent. There is a possible doubt as to their identity. But, after considerable thought, the writer has reached the decision that the Siirt and Kerbent gypsiferous shales are different from the shales of Harbol and Zivengok. The latter are older.

The limestones on the north side of the thrust at Harbol differ lithologically and in the matter of succession from the escarpment-forming limestone on the south side of the structure and are referred to the Eocene. At places this limestone contains *Nummulites* in profusion. Nowhere was its relationship with the red beds mentioned in the preceding paragraph noticed.

Cretaceous.—Underlying the red beds are olive-green sandstones and shales. There is an oyster bed near the top of the formation. West of Dergul and at Sigrik large gastropods and well preserved pelecypods suggestive of the Maestrichtian were collected. The asphalt at Sigrik and the oil at Zivengok are found near the top of this formation. These

and the underlying dark gray shales are well developed in the Rohsur valley, in the Kerjos valley, and in the valley between Kerboran and Kermab. The thickness of this group is estimated at approximately 200 meters (650 feet).

Underlying the foregoing beds are somewhat thick dark gray and black calcareous shale and shaly limestone. The base is not seen anywhere except in the Harbol overthrust. Its estimated thickness is between 400 and 500 meters (1,310-1,640 feet). It is distinctly a limestone near its base.

Underlying the shales dark limestone is seen at Hizil Su on the Iraq side of the creek.

Paleozoic.—In the Harbol region, on the Harbol-Goyan road, approximately 2 kilometers northeast of the town, at a place 450 meters (1,476 feet) higher than Harbol village and almost at the divide, 4 feet of black shaly limestone dipping west crops out. It contains fossils in profusion, including ***Productus*** and some corals. The section here is greatly disturbed. Several large faults can be observed within a radius of 3 kilometers; it is a region of thrusts.

Igneous rocks.—Basalt flows already mentioned in the discussion of the Pleistocene are restricted to the right bank of the Tigris. They have typical columnar structure near Jezire, but as exposed on the road between Jezire and Midyat they are principally vesicular. Cone-shaped Elim Dag is probably the source. The vicinity of Diarbekir, too, shows extensive basaltic flows.

STRUCTURAL GEOLOGY

REGIONAL

The formations in the area have a regional dip toward the south. This south or slightly west-of-south tendency changes with irregularities in structure.

The major structural axis is east-west. It is more pronounced in the north than in the south and much more pronounced in the east than in the west. Strong overthrusts are present. But most structures in the area are asymmetrical anticlines with their southern flanks much steeper than their northern flanks. Many of the south limbs are vertical and some are faulted.

As a rule the folds south of Savur indicate more gentle dips, though a slight asymmetry may be observed here also.

LOCAL

Harbol structure.—At Harbol there is a faulted anticline with the northern limb thrust over. Several secondary faults are visible within

the black shale and limestone series. These are sufficiently defined to be photographed on the hill immediately west of Harbol. The tectonics of the Harbol area are complex. The north flank with gentle north dips exposes a thickness of 500 meters or more without its counterpart being shown on the south side. The formation on the north side is evidently older. In one locality even Paleozoic is found brought up with a thrust.

The asphalt of Harbol is found approximately along the thrust plane of the fault. The considerable heat generated during these earth movements distilled the oil, leaving the asphaltic residue.

Rohsur valley structure.—This is a large structural "high," west of Harbol. Immediately after crossing the Kasyrik Gorge near Jezire, where Rohsur Su cuts a channel in vertical beds, one finds the underlying red beds and greenish sandstone dipping more gently toward the south. Within 3 kilometers the same beds show consistent north dips. The structure is closed at the west by well defined, continuous west dips. Locally a few east dips were also observed, making a closed structure in dark shales. The dips undulate farther north, but maintain a general northerly attitude as far as the Sharnak Mountains. Immediately south of the Sharnak Mountains several sharp reversals are observed. The Sigrik asphalt deposits are close to this end. The value of this Rohsur valley structure is dependent on the presence of an underlying reservoir horizon. This is believed to be supplied by the dark gray limestone observed on Hizil Su east of the village of Slip. The objection to this explanation of the structure is not so much the absence of a reservoir bed as the fact that the source beds are exposed.

Zivengok structure.—This structure is situated approximately 25 kilometers west of Sharnak. The fold is sharp. Near its crest light oil exudes. But close to this locality are beds dipping 60°-70° and some which are vertical. Besides the oil, a conglomeratic sandstone with some asphalt is found. The structure is probably faulted. The limestone escarpment closes three sides of the structure, which extends east and west. The distance from rim to rim in the limestone is not much more than 2 kilometers. The lowest beds exposed are the red shales and sandstones and the upper part of the olive-green series.

Kerbent structure.—Kerbent is approximately 12 kilometers northeast of Kerboran. The structure is in beds believed to be Miocene. The dips are gentler, ranging from 15° to 25°. Here also the oil exudes from the crest of the anticline. The structure closes toward Chelik on the Tigris and extends east and west.

Kidmis structure.—This is approximately 10 kilometers south of Siirt along Bohtan Su. It is in the chalky Miocene limestone. The dips

are gentle, and the structure seems closed on all sides. An oil seepage at a place near the crest of the anticline on Bohtan Su is credibly reported. Outside of the fold, but near it, warm sulphur waters issue. The fold is in a downthrown block, as indicated by the appearance of the red shales, underlying the limestone, 150 meters higher than the limestones south of Beloriz.

Kerjos structure.—Approximately 20 kilometers north of Midyat is the anticlinal Kerjos valley. This structure is the easterly extension of the Kerbent structure, but is separated from it by a saddle. The structure is shown in the dark gray shales which cover this wide valley. On the south flank and outside the town limits of Kerjos there is an asphalt bed in the lower part of the red shale and yellowish sandstone series (Fig. 4).

Savur structure.—This is a westward continuation of the Kerbent and Kerjos structures. It differs from the others in having a north-south, instead of an east-west axis. It is closed on the north by the meeting of the two mountains that flank Savur Creek. The structure is shown in limestone, believed to be Miocene, and is closed by gentle dips.

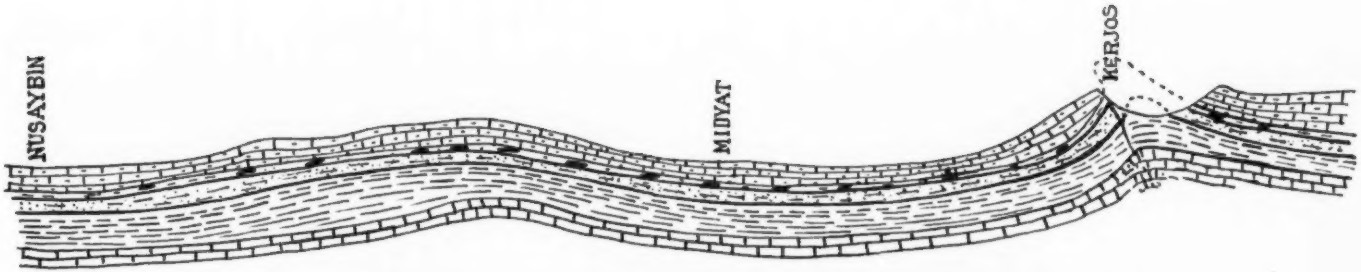
Mardin structure.—The town of Mardin is situated on the gently dipping north flank of this structure. The south limb, though steeper, does not show dips of more than 45°. The structure has an east-west trend and is shown in beds believed to be Miocene. It has a distinct advantage in being located nearly on the railway. The outcropping beds are high in the section, and drilling can be done with confidence.

Turabidin structure.—Fifteen kilometers north of Nusaybin the plains topography changes to moderately rough hills extending approxmately east and west. The dips are gentle toward the south. Farther up the valley, in the low hills approximately 30 kilometers north of Nusaybin and in the vicinity of the villages of Jebel Gras and Talat, the dips turn north. For several kilometers, the strata dip north and northeast. The outcropping chalky limestone, cavernous in places, is regarded as either upper Miocene or Pliocene. The Turabidin structure is the easterly prolongation of the Mardin structure.

ECONOMIC GEOLOGY

OIL INDICATIONS

There are liquid oil seepages, asphalt deposits, and hydrogen sulphide emanations in many places in the area. References are made only to localities actually visited.



HYPOTHETICAL SECTION FROM NUSAYBIN TO KERJOS

MARDIN REGION

Plio-Miocene Cavernous Limestone

Miocene Gypsiferous Pink Shales

Greenish Sandstones & Shales

Bluish Gray & Black Shales

Massive Limestone

FIG. 4

Zivengok.—Twenty-five kilometers west of Sharnak oil issues from two places within 500 meters of each other. The one from which samples have been collected is on Shems Creek before it joins Zivengok Creek and near the Nehik mill. The other is farther east, below the junction of Zivengok and Shems creeks. The pit from which the samples were taken is 1 meter in diameter and produces 2 gallons per hour. The oil is brown and light. The water over which it gathers is sweet, obviously coming from the creek through the gravel. The other locality, a few hundred meters farther east, was covered by a landslide, but a little excavation showed live oil oozing out. A short distance northwest of the first locality mentioned near the Nehik mill, vertical conglomerate with asphalt may be seen. Several other asphalt localities are known in this valley. Stratigraphically the oil occurs near the contact of the greenish sandstones with the overlying red beds.

Kerbent.—Twelve kilometers northeast of Kerboran, liquid oil exudes from the crest of the anticline 230 meters below the village of Kerbent and 20 meters above the creek bottom. Oil oozes from three different places all within 150 meters of one another. At Kerbent the exudation is slow. It requires patience to collect a very small sample of the liquid. It dries quickly, making a sight similar to the "chapapoteros" of Mexico.

Siirt.—On the right bank of Bohtan Su, 10 kilometers south of Siirt, between Kidmis and Beloris but nearer Kidmis, liquid oil is credibly reported to issue. At the time of the writer's visit the river was high, and it was not possible personally to verify the report. To do this the investigator should visit the locality during August or September. However, from the details given by several independent and trustworthy natives, there seems no doubt as to its presence. Bohtan Su here flows along the axis of the Kidmis anticline.

Harbol.—Approximately 1½ kilometers southwest of the village of Harbol and east of the Harbol-Besbin path, three different localities with large and pure asphalt lenses are seen. The asphalt is lenticular and occurs along the trace of the thrust fault mentioned. At the actual excavation the lens is 10 meters thick. The estimate made by the department engineer that the amount of available asphalt here is 20,000 tons is believed to be correct. The asphalt, which is of high quality, formerly supplied the steamboats plying on the Tigris. It was then known as coal and is so marked on the British maps.

Hizil Su.—In the locality known as Shikefte Hazinan, approximately 1 kilometer north of the Iraq garrison, in the dark gray shales near the

base of the red beds and close to the axis of a small anticline, some of the vertical joints of the bluish gray shales may be observed to contain slightly viscous asphalt. Most of the joints, however, are filled with calcite. The occurrence here is not one of migration. It is probably produced *in situ* as a result of heat and pressure coincident with the forming of the structure. The dark gray shales are carbonaceous.

Sigrik.—Approximately 8 kilometers southwest of Sharnak, in the greenish sandstones and shales, somewhat impure asphalt in considerable quantity is found. The impurity is sand and sulphur. Asphalt is found at several horizons. Some of it is across the bedding. The locality shows evidences of burning indicated by many coalesced fragments such as are observed in metallurgical plants. In the vicinity of the asphalt, four cone-shaped knobs are observed along a N. 50° E. line, all close to one another. It may be noted that the trend of the structural axis in this vicinity is northeast. No effort was made to compute the quantity of asphalt here, but it is approximately twice as much as at Harbol. This locality is also referred to in the British maps as a coal deposit.

Dergul.—A small amount of asphalt was found on a side hill 50 meters below the crest of the mountain, approximately 2 kilometers west of Dergul. This is a small, almost abandoned village approximately half-way between Jezire and Sharnak. The asphalt resembles the product at the Sigrik locality.

Kerjos.—Less than a kilometer east of the town of Kerjos (20 kilometers north of Midyat) a good grade asphalt, less indurated than that at other localities, is found at two places within 200 meters of each other. The asphalt bed is in the yellowish light-colored marls immediately below the pink beds. These beds dip south, and the asphalt is related to a local fault.

South of Siirt.—A large volume of warm sulphur water issues from the crevice of the limestone along Bohtan Su, 12 kilometers south of Siirt and 2 kilometers south of the oil seepage mentioned. One of the orifices is a large pool in a limestone cave. It is immediately south of the Kidmis structure. Sulphur springs are on both banks of Bohtan Su.

Kermab.—Approximately 12 kilometers east of Kerboran and on both banks of the Tigris at the locality known as Kermab, copious quantities of hot sulphur water issue. The occurrence is in connection with a major east-west fault just south of these hot-water baths.

OIL DEVELOPMENT

There has been no petroleum development in this region. A short distance across the border from Kurkut, near Zaho on the Iraq side,

several shallow pits are being operated at present. The oil is taken on "keleks" down Habor Su and the Tigris to Mosul.

OIL POSSIBILITIES

From the Persian Gulf northwest through Persia and Iraq, for 1,200 miles, the longest stretch of more or less continuous surface indications anywhere known extends into the present boundaries of Turkey. Thus, there is little doubt that parts of Turkey form part of a major petroliferous province. After a reasonable assurance of this important factor, it is desirable to refer to some of the more important geological conditions. It is generally agreed that the following criteria must be examined in an entirely new territory. In a known area such as that east and south of the Balcones fault in Texas, inquiry can be limited to the question of structure alone, but in undeveloped regions other factors must be ascertained.

1. There must be present in the region sufficient thickness of a somewhat widely distributed sedimentary formation capable of acting as source bed. These are mostly black carbonaceous shales and in some places limestones.
2. The source material must have been subjected to heat and pressure to segregate the oil.
3. There must be a reservoir bed for this freed oil.
4. There must be a suitable structure to permit the accumulation of the petroleum.
5. This structure must be covered with an impervious bed to keep the oil from migrating.
6. The reservoir horizon must not be (with few exceptions) below the source bed.
7. The heat and pressure must not be so severe as to destroy and dissipate the hydrocarbon.
8. The structure must not be so small as to preclude its being a commercial pool.
9. The region must not be faulted so much as to break up the reservoir and create many channels of escape.
10. Preferably, but not necessarily, there must be actual evidences of petroleum in the region.

These conditions are satisfied within the area, and it is not unreasonable to consider that some parts of this area have decided possibilities of producing oil in commercial quantities.

Anatolian Plateau

The Anatolian Plateau is a large basin broken by many faults. The oldest rocks are on the northern shore of the Black Sea. Earth movements have occurred at very recent dates. The Zigana Mountains, immediately south of the Black Sea town of Trabzon, have an elevation of 2,000 meters (6,560 feet) 50 kilometers from the shore. The mountains are all very young, the valleys narrow, and the streams rapid. Toward the south the mountains become progressively higher. The altitude of Kop Dag, south of Zigana, is 2,970 meters (9,600 feet); Palan Doken, at the base of which is the town of Erzerum, is 3,100 meters (10,168 feet); Bin Gol Dag, farther south, is 3,250 meters (10,660 feet); and Suphan Dag, on Lake Van, still farther south, attains an elevation of 4,400 meters (14,432 feet). Earth movements have been severest in the north and the east. It is also here that igneous activity has been most intense.

It is considered best to give a concise and separate geologic discussion of the localities generally mentioned in connection with petroleum possibilities in this general region.

JEMAGIL

Jemagil is 36 kilometers in an air line and 46 kilometers by the road east of Bayburt. Bayburt itself is 200 kilometers south of Trabzon on the Black Sea. The automobile road to within 10 kilometers of the village is fair. The last part can be traveled in an automobile in dry weather with caution, and if Masat Dere is not too high. The region is mountainous, and the valley where the village is situated is 1,850 meters (6,068 feet) above sea-level. Jemagil is a group of four villages in a distance of 5 kilometers. Some of the mountains near by attain high elevations. Ak Dag, immediately north of the village, is 2,850 meters (9,348 feet), Jejen Dag, at the south, is 2,900 meters (9,512 feet), and Kop Dag, at the southwest, is 2,980 meters (9,774 feet) above sea-level. The region is barren of trees. Wheat raising is the principal occupation. There is plenty of water; and the climate is cold in winter, cool in summer, and healthful.

STRATIGRAPHY

Pre-Cretaceous.—The rocks exposed at the gorge in which the seepage occurs are believed to be pre-Cretaceous because they are much distorted and indurated and because they underlie Cretaceous limestone. The series is referred to as Kiran Oglu quartzite and conglomerate. It is hard quartzitic conglomerate and sandstone interbedded with dark gray indurated shales. The section is at least 600 meters thick. It contains

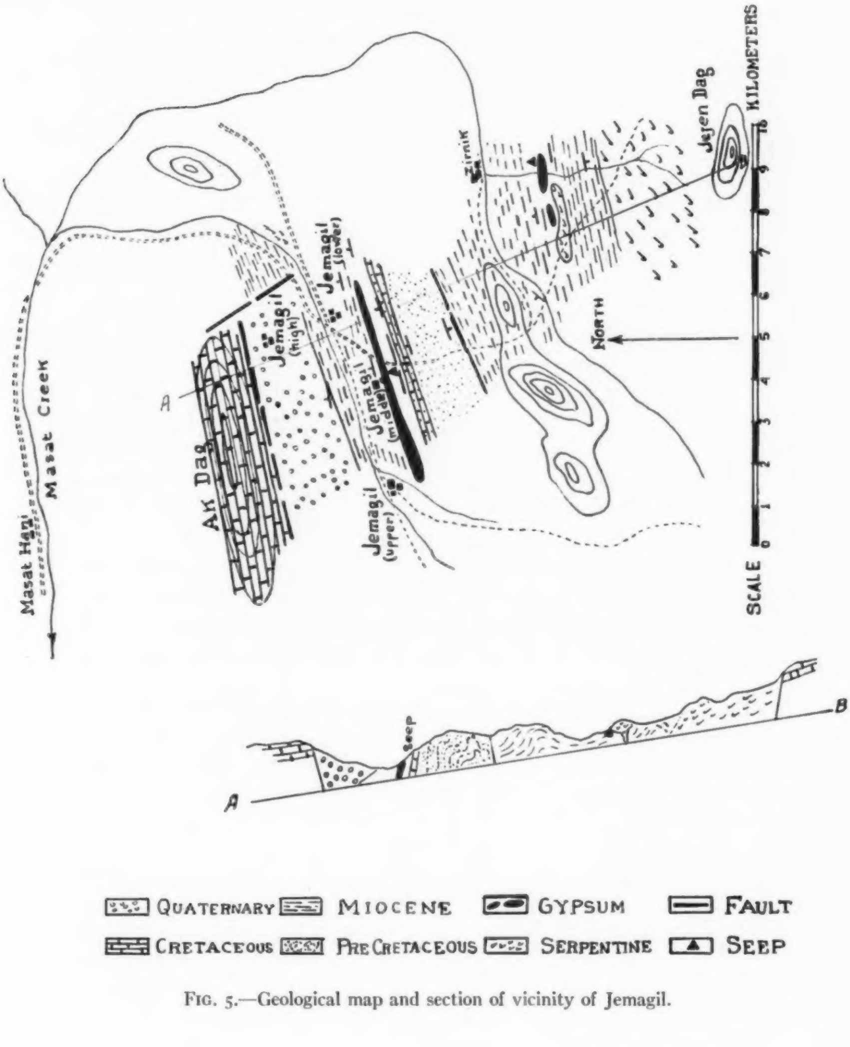


FIG. 5.—Geological map and section of vicinity of Jemagil.

ledges of grayish blue lithographic limestone without chert. The beds are vertical and overturned.

Cretaceous.—South of lower Jemagil, at a place where rock is locally quarried, light-colored homogeneous limestone not more than 20 meters thick is exposed, containing a few ammonites of the *Schloembachia* type, probably of Turonian age. At its base a conglomerate is seen separating it from the Kiran Oglu series.

Ak Dag limestone is light-colored, massive, and conspicuously jointed. Its position in the stratigraphic column is obscure, but a "float" ammonite was found at its eastern end not far from the road. It is probably Cretaceous. Its thickness is approximately 500 meters. It is a reef formation.

Tertiary.—The section from the Turonian limestone on the north flank of Kiran Oglu Dag to the more recent conglomerates north of Jemagil Creek is Tertiary, and some of it certainly Miocene. At the base is a marly limestone from which the seep issues.

Overlying these light-colored marls are gray and pink marls of undetermined thickness. They are not less than 100 meters thick. Next comes a gypsum, which is somewhat extensively developed from one end of the valley to the other. The gypsum here is estimated to be 180 meters thick.

Overlying the gypsum is a fossiliferous bed of limestone and marl. The exact fossil locality is at the north edge of Orta Jemagil and south of Jemagil Creek. It contains echinoids, a profusion of large and small pectens, pelecypods, and bryozoans. The fauna has a decided Miocene appearance.

South of Zirnik village, near the serpentine intrusion and gypsum, are found grayish blue limestone and shale containing *Foraminifera* (*Lepidocyclina ?*) and other poorly preserved fossils. Some specimens at this locality have a distinct petroleum odor, and a few contain vugs filled with light oil. It is believed that these may be correlated with the beds mentioned in the preceding paragraph.

Quaternary.—North of Orta Jemagil, not far from the foot-bridge over Jemagil Creek, is a bed of conglomerate dipping north and seemingly overlying the Tertiary section. Between this locality and that of the massive limestone of Ak Dag is a thick section of continental deposits that is probably Quaternary. Ak Dag limestone appears higher than these conglomerates because of faulting, as evidenced by topography and the presence of springs.

Igneous.—A serpentine intrusion is found south of Zirnik. From this point south dark igneous rocks become more noticeable, and farther south cover large areas as intrusive sheets. In the east end of the valley of Jemagil Creek also are dark igneous rocks. The igneous activity dates from late Tertiary.

STRUCTURE

The region of Jemagil is one of severe folding and faulting. Block faulting is characteristic. The beds and the larger faults have an almost east-west trend (N. 65°-70° E.). Only the principal faults need be discussed. One of these is a strike fault at the base of Ak Dag, extending approximately east and west. Although Cretaceous in age, the Ak Dag limestone is 400 meters higher than the Miocene beds below in the valley. A north-south fault abruptly cuts this limestone on the east. In the valley a small fault is associated with the seepage, and the evidence of faulting is clear at the quarry between the Cretaceous limestone and the Tertiary in front of it. Mud volcanoes indicate a fault at the south edge of Kiran Oglu formation. These are normal block faults. A small reversal is indicated south of Zirnik. The serpentine there found its way to the surface through the weakness at its apex.

OIL INDICATIONS

Approximately 2 kilometers S. 30° W. of lower Jemagil there is a shallow well from which oil was taken in former years by inhabitants. At the time of the writer's visit the well was covered by débris. When the well was cleaned, iridescence was observed on the top of the water. The marls forming the wall gave a strong odor of light oil.

One and a half kilometers southeast of this place, in a secondary valley, mud volcanoes occur. These were dry at the time of the writer's visit, but there was no doubt as to their previous existence. Small amounts of water with some carbonic acid gas were issuing from these sources.

Four kilometers northeast of Jemagil, on the road to Bayburt and near an igneous dike, highly mineralized water springs are found on both sides of Jemagil Creek. Carbonic acid gas occurs plentifully in these sources.

South of Zirnik the limestone near the serpentine plug and gypsum has a decided petroleum odor. Some specimens contain vugs filled with free oil. This oil is believed to have migrated along a fault line and lodged in the solution cavities of the limestone.

PULK (TERJAN)

Pulk is a village 6 kilometers north of Mans, 30 kilometers west of Terjan, in the Vilayet of Erzurum. It can be reached with an automobile by a secondary road that turns off from the Erzurum-Erzinjan highway at the bridge over Kara Su just before this joins with Tuzla Dere and becomes the Euphrates. This bridge is 113 kilometers from

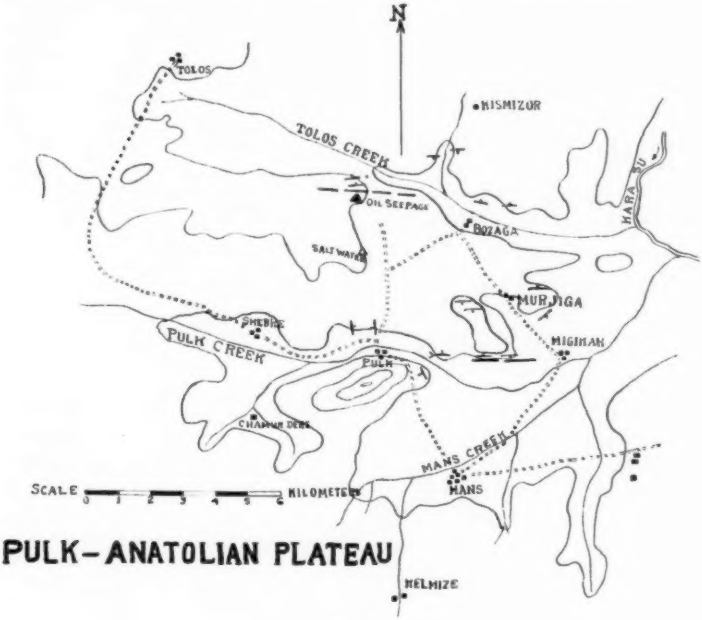


FIG. 6

Erzurum and 90 kilometers from Erzinjan. The region has plenty of water and fertile ground, and is healthful. The valleys have an elevation of 1,500 meters (4,920 feet), and the surrounding hills are approximately 2,000 meters (6,560 feet) above sea-level. Keshish Dag, which separates the valley from the Erzinjan valley, attains an elevation of 3,450 meters (11,296 feet).

STRATIGRAPHY

The oldest rocks of the region are the bluish gray metamorphosed limestones with quartz veins and intrusions of serpentine freely exposed

south of Mans toward Marput Dag. These are certainly pre-Tertiary and probably pre-Cretaceous.

Limestones with *Nummulites* and other Eocene fauna are reported in the mountains west of Pulk. The prevalent yellowish and greenish gray gypsiferous shales are Miocene. They contain thin seams of lignite north of Murjiga near Tolos Creek, and are correlated with the gypsiferous Miocene shales found in other parts of Turkey.

On the road from Mans to Pulk, at the east end of Pulk Mountain, these shales are seen to dip under pinkish clastic limestone forming the hill at Pulk.

North of the seepage, thick conglomerate and conglomeratic shales and sandstones are exposed. The total thickness of the series is approximately 500 meters. The lower 300 meters is reddish, hard, coarse, and is cemented with calcareous material. The upper part is composed of thin layers of gray shales with fine conglomerate intercalations.

Quaternary.—These are very coarse torrential deposits forming the apron of the hill south of Mans. The fluviatile silts of Mans and Pulk creeks are the more recent deposits.

STRUCTURE

The fact that the conglomerates abut against the lower gypsiferous shales at the seepage, together with their steep and northerly dip, strongly suggest a fault at this place. As indicated in Figure 6, the local structure is believed to be a faulted anticline. The oil seeps follow the fault plane. The anticlinal structure is inferred from the persistent south dip in the north end of Kizil Kaya, opposite Murjiga. In the conglomerate series itself there is evidence of movement and faulting. It is interesting to note that these conglomerates do not appear south of the seepage.

Near Pulk, the south end of Kizil Kaya exhibits extraordinary structural attitudes. For example, the east end of the hill dips very steeply south, and the west end, approximately on the same strike, dips steeply north. At the west of this torsional faulting is a nose of an anticline.

At Pulk the structure extends north and south. North of the creek the limestone dips west, and a little farther west on the road to Shebke it dips strongly east. It is too sharp, aud when the incompetent nature of the rocks involved is considered, a fault rather than a syncline must be postulated.

OIL INDICATIONS

Six kilometers north of Pulk and 200 meters north of a prominent willow tree there are two hand-dug wells which show oil iridescence and have a typical kerosene odor. The Russians have taken some oil from these wells by skimming collected seepage oil. Approximately 1½ kilometers south of the seepage on the west side of the road, there is a well with strong brine locally used for salt.

KATRANLY

Katranly (Fig. 7) is 40 kilometers south of Erzurum. The Palan Doken Mountains (Fig. 7), which separate it from the valley of Erzurum, reach elevations greater than 3,100 meters (10,168 feet) and the pass itself is 2,980 meters (9,775 feet). The valley of Katranly is between 1,900 and 2,000 meters in elevation. The road over the mountain is steep and very rough. The trip was accomplished by automobile and truck, with difficulty. The climate is salubrious, but cold in winter. The pass over Palan Doken is covered with snow from October to May, or six months of the year. The drainage is into Araxes River, which flows eastward to the Russian border and the Caspian Sea.

STRATIGRAPHY

The oldest exposed rock is a marmorized limestone which appears in the northern part of the area brought up through an overthrust from the north.

Miocene.—At Tash Kesen, on the east bank of the creek, a section composed of limestone, bluish gray shale, and calcareous sandstone, is exposed. In the marly shale member *Cardium*, *Mactra*, *Dreissensia*, *Cypris*, *Pecten*, and *Modiola* are found, indicating Upper Miocene. The section is also seen on the road from the seepage to the villages of Huseyn Aga and Madrak. It is from 250 to 300 meters thick.

The section exposed at the salt works, 6 kilometers south of Tash Kesen, shows vertical and overturned beds of limestone overlying gypsiferous clay shales and underlying marls. The relation between these and the succession mentioned in the preceding paragraph is not known.

Quaternary.—The pyroclastic formation of the seepage is probably early Quaternary. It is a coarse cross-bedded sandstone composed principally of basic igneous rocks and their decomposition product and white tuffa.

Igneous.—The region is extensively covered with igneous rocks of basic composition. These are of at least three periods. The youngest is a basaltic flow forming a mantle over large areas. It is fairly recent,

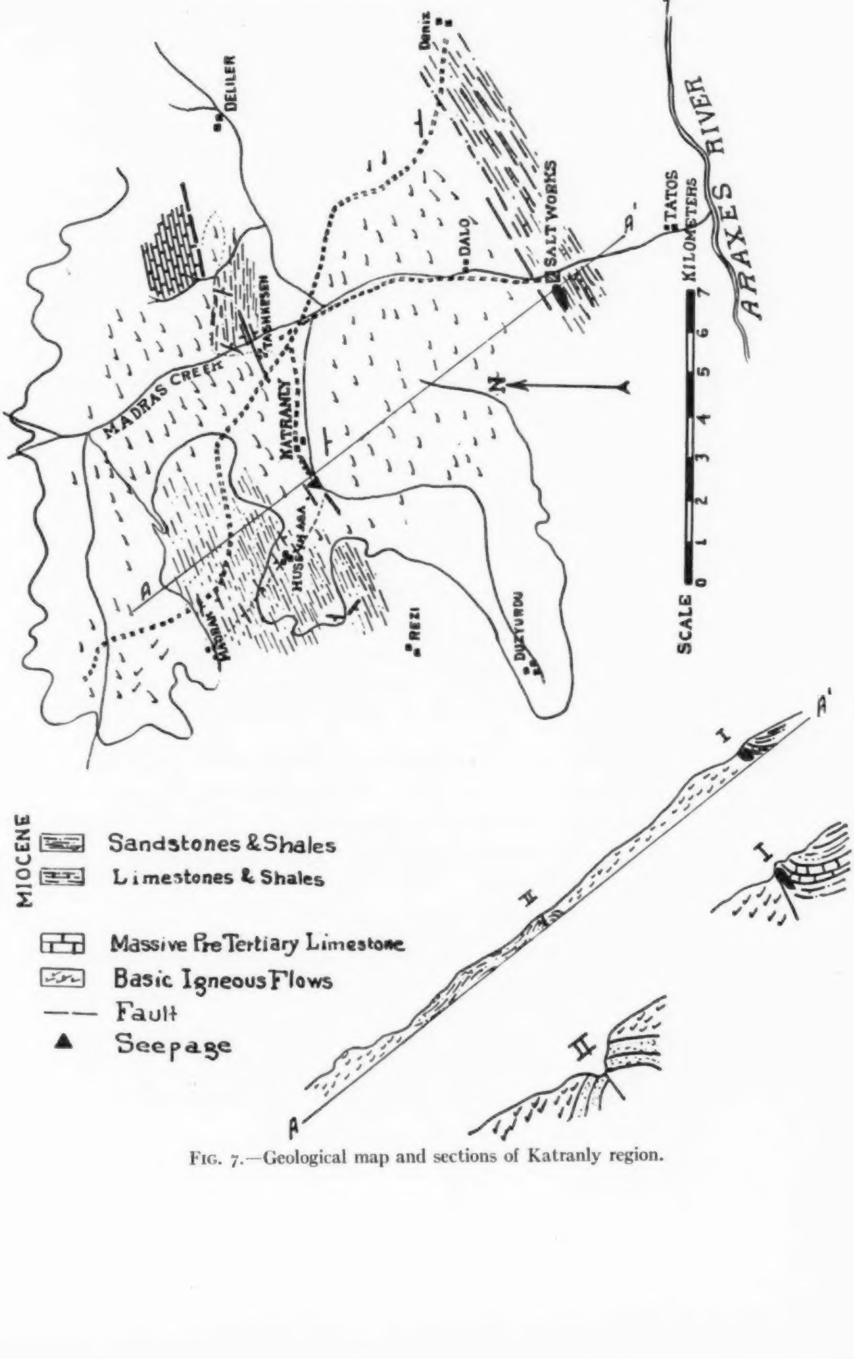


FIG. 7.—Geological map and sections of Katranly region.

younger than the pyroclastic formation mentioned. There is an older flow, probably at the end of the Tertiary, the particles of which compose the pyroclastic sediments. The serpentine in the north is certainly older than either of the other two flows.

STRUCTURE

The structural trend of the region is N. 65°-70° E. The area discussed is in the front of an overthrust. This brings the marmorized limestone to some of the high hills in the northeast. Therefore, the folds with small amplitude which are seen at Tash Kesen and on the road between Huseyn Aga and Madrak are compressional, affecting only the softer Miocene formation.

At the salt works the structural condition is very pronounced. The attitude of the limestone and the gypsiferous shales is suggestive of a salt dome.

OIL INDICATIONS

Approximately 1½ kilometers west of Katranly, a few meters from the 30-foot derrick still standing, light paraffine-base oil seeps on the north bank of the creek. The Russians have produced some oil here from a shallow well, and Abdurrahim, a merchant from Erzurum, has worked before and since the World War sinking a small well to a depth of 20 meters by hand-operated percussion drilling. His verbal statement to the writer, also verified by the stories of independent observers, was that he filled several 5-gallon cans with oil he got from this well and used this oil for local lighting. The work has been stopped for almost 3 years, and the seepage only gives evidence of oil. By cleaning the seepage 2 or 3 liters can be obtained in 1 day.

Six kilometers south of Tash Kesen, there is a brine well which flows at the rate of 25 kilos of salt water per minute, containing 200 grams of salt per kilo of water. During one season the works here produce between 800,000 and 1,000,000 kilos of pure salt. As it has been operated for at least 45 years, the source is clearly a very large salt mass.

DIVANI HUSEYN-NEFTIK

Divani Huseyn is approximately 25 kilometers south of Hinis, and 115 kilometers south of Erzurum. It can be reached from Erzurum in the north via Tash Kesen and Hinis, and from Mush from the south. The use of an automobile is not recommended. The region has plenty of water. North of Hinis the drainage is into Araxes River and the Caspian Sea. But from Hinis south, including the Divani Huseyn area, the drain-

age is into Murat Su, which is an important branch of the Euphrates. Elevations in the valley area are between 1,800 and 1,900 meters; the principal hills, such as Hamurpet, attain a height of more than 2,900 meters (9,512 feet), and Bin Çol Dag attains a height of 3,250 meters (10,660 feet).

STRATIGRAPHY

A large part of the region is covered with lava south of the creek, but toward the north some patches of sediments may be observed.

Cretaceous.—The oldest exposed rock is a massive, light-colored limestone forming the hill immediately west of Shah Verdi. It contains few fossils. The writer found several well preserved pectens.

On the path between Divani Huseyn and Shah Verdi, ½ kilometer before one reaches the latter village, on a small creek, limestones and shales are exposed, with a profusion of fossils. Lithologically this limestone is quite different from that mentioned in the preceding paragraph. This is well stratified. The collection gave numerous specimens of *Exogyra* (*costata ?*) of the Upper Cretaceous and some Cretaceous pectens.

Tertiary.—A thick section of reddish sandstones and conglomerates belonging to the lower Tertiary overlies these limes and shales. It is 300-350 meters thick.

Over the conglomerate lie gray shales with hard sandy lime intercalations. The gray shales are separated from the underlying red beds by a transition series. Here gray shales are found in thicknesses of 2-5 meters interbedded with the red beds.

At Demirji Koy the gray shale group begins with (1) a gray sandstone, (2) above this 100 meters of shales, (3) gray argillaceous limestones 20 meters thick, (4) gray shales and calcareous sandstones 125 meters thick, and (5) on the top gray argillaceous sandstones approximately 30 meters thick. The total thickness is 250-300 meters. Following the creek upstream from Demirji, argillaceous limestones with fossiliferous calcite veins are found. Here many *Turritella* and pectens are found. They are Tertiary.

At the Hamurpet Dag, on the path from the seepage to the village of Halil Chavush and near the crest of the mountain on the south flank, a light-colored fossiliferous limestone is found. It contains *Foraminifera* and other Tertiary fossils. The writer did not see these limestones in the valley on the north.

At Demirji Koy the top of the bank on the north side of the creek is covered with a white foraminiferal chalky limestone containing many

sharp-beaked small lamellibranchs. Here *Helix* and *Nuculus* are found. The bed is 20 meters thick and is considered to be Pliocene.

Quaternary.—The spring deposits north of Neftik, along the south flank of the mountain, as well as the gravel and loosely consolidated fluviatile deposits of the hills, are Quaternary.

Igneous.—Ninety per cent of the area is covered with lava of the basalt type. The latest flows are Quaternary to Recent.

STRUCTURE

In the small creek flowing north on which the seepage of Divani Huseyn is located, there are three reversals within 500 meters. The flattest dip is 65°. The attitude of the beds is approximately east and west.

At Demirji a north-south fault brings the red beds up to a position higher than the gray shales. Along the creek towards Divani Huseyn other faults equally clear are found. Here the shale makes complicated "S" turns over more competent red series.

North of Divani Huseyn where the salt-water seepage is found, the beds make very acute flexures.

At Shah Verdi the relation between the Cretaceous limestone and the red beds can be explained only by faulting or very severe folding. Thus, it will be observed, the region has been subject to severe earth movements.

OIL INDICATIONS

Approximately 500 meters south of the village at Divani Huseyn, oil is found to issue from gray shales. The Russians have dug a number of trenches and obtained a small quantity of seepage oil. At present one can collect a bottle by patient work.

At the south flank of Hamurpet Dag, at a point N. 15° E. of Neftik, there are two pits from which the Russians have collected a small amount of oil during their occupation. The oil issues with bubbles of gas (H_2S) and salt water. This locality is approximately 18 kilometers east of the seepage at Divani Huseyn.

HASAN KALE

Hasan Kale is 40 kilometers east of Erzurum, with which it is connected by a good road and a narrow gauge railway. This narrow gauge railway extends to the Russian border and connects with the Russian railway system. Erzurum, however, does not connect by railway with the seaport of Trabzon. It is planned that it be linked with Sivas during

the next 5 years. The region varies in elevation from 1,600 meters (5,248 feet) at Pasin Ova to more than 3,050 meters (10,000 feet) in the mountains on the north and on the south. There is plenty of water, and Pasin Ova is famed for its fertility. The drainage is into the Araxes and the Caspian Sea.

STRATIGRAPHY

There are too few exposures to make possible the construction of a stratigraphic column or even to give a comprehensive idea of the stratigraphy. The region is covered with alluvium and eruptives. The best exposure is along Araxes River east of Choban Kopru. Here a section of bluish gray shales with conchoidal fracture containing many diminutive gastropods of Miocene appearance is found. The section is at least 60 meters thick. The base is pure clay shale and the top is a sandy shale with intercalations of pure sand, not well consolidated. A small shell with triangular cross section is prominently present. These same shells are plentiful at the village of Tuda Viren.

At Hertef a white ash and gravel bed 30 meters thick is probably Pliocene. The gravels north of Koprukoy are believed to be Quaternary.

Igneous.—Eruptives cover a large part of the area. The igneous activity has continued to a very recent date. The rocks are mostly basic and both extrusive and intrusive in character. At Hasan Baba Dag the formation is a trachyte porphyry showing decided amygdaloidal structure suggesting schistosity.

STRUCTURE

Faulting characterizes the region. A prominent east-west fault passing through Hasan Kale extends from one end of Pasin Ova to the other. Along this fault and on the secondary faults parallel with it there are several mineral-water springs. These are cold, warm, and hot; this is explained by the different depths from which water comes to the surface. Oil at Hasan Kale issues from a spring together with lukewarm mineralized water.

The structure of the valley is a complicatedly folded, downthrown block.

OIL INDICATIONS

From six different places oil exudes near Hasan Kale within 500 meters of the town and the baths. These places are approximately on an east-west line. At Hasan Kale itself there are three thermal baths all close to one another with temperatures of 27°, 38°, and 42° C. They contain iron, sodium sulphides, and iron oxide. Twenty kilometers

east of Hasan Kale and north of Kopru Koy cold mineral water with a large amount of carbon dioxide is found. Farther east, at Tuda Viren, the water of the village is decidedly sulphurous. Five kilometers west of Hasan Kale at Serche Bogaz, a mineral-water spring with temperature of 20° C. exists. It is charged with carbon dioxide. Seven kilometers west of Hasan Kale, at Asboa, a warm mineral spring used as a bath exists.

KORZUT-ERJISH (VAN)

Erjish is 320 kilometers southeast of Erzurum and 650 kilometers from the port of Trabzon along the highway. It is nearly on the shores of Lake Van, being 3 kilometers inland. The elevation of the lake is more than 1,700 meters (5,576 feet). The lake is surrounded by mountains attaining elevations of 3,000 meters (9,840 feet). Suphan Dag, on the north side of the lake, is the second highest mountain of the Turkish Republic. It has an elevation of more than 4,400 meters (14,432 feet). Water is very plentiful in the region, though there are no large rivers. They all drain into the lake. The lake water is notably salty. Korzut is 40 kilometers from Erjish, near the northeastern corner of Lake Van, and Chakir Bey is 18 kilometers north of Erjish on Zeylan Dere.

STRATIGRAPHY

Little can be said about the stratigraphy of the area. It is largely covered with eruptives. South of Korzut, at the locality where some oil has been obtained, the section is composed of igneous rocks, metamorphosed shales, and conglomerates. Dips are obscure. On the north, between the seep and the village of Korzut, are less metamorphosed shales and a light-colored limestone. Except for this limestone, which is probably early Tertiary,[1] the question of age is problematical. It is reasonable to assume that the metamorphic rocks are Paleozoic. Southwest of Korzut on the cliffs near the village of Anguzek, one finds well bedded late Tertiary pyroclastics.

At Erjish the cliffs surrounding the east and the north of the town expose a massive light-colored chalky limestone with *Bryozoa*, corals, pectens, and *Foraminifera*. It is younger than the limestone near Korzut. It is probably lower Miocene or upper Oligocene.

Cross-bedded sandstones appearing near Erjish and on the way to Chakir Bey are very late Tertiary, or possibly Pleistocene.

The igneous rocks are evidently of different ages. Volcanic activity must have continued until very recent time.

[1]Kowalewsky, *Petroleum Zeitschrift* (January 10, 1926).

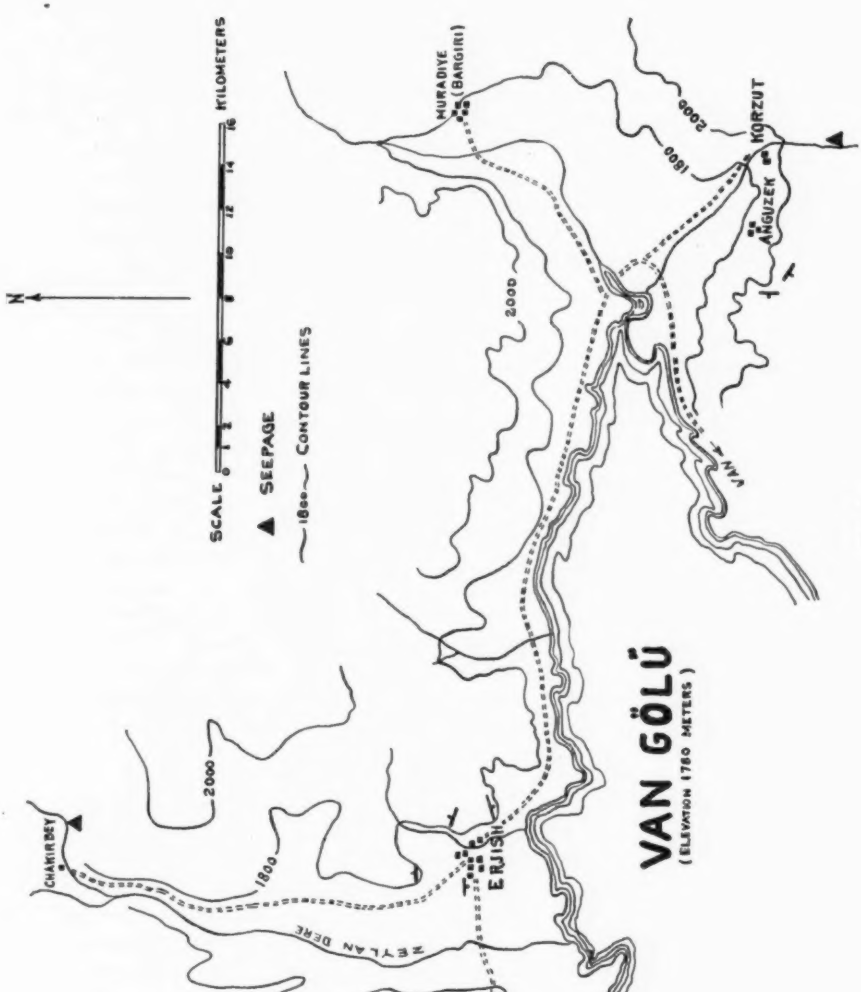

VAN GÖLÜ
(ELEVATION 1780 METERS)
ERJISH
CHAKIRBEY
ZEYLAN DERE
MURADIYE (BARGIRI)
KORZUT
VAN
SCALE
KILOMETERS
SEEPAGE
1800 CONTOUR LINES
2000
1800
N

FIG. 8

STRUCTURE

The structural condition at Korzut is complex. Faulting is seen at several localities, and the beds strike almost east-west and dip almost vertically.

At Anguzek the younger pyroclastics show a tendency to nosing, and their inclination is moderate, from 6° to 10°.

The cliffs partly surrounding Erjish indicate an anticlinal condition north of the town. If the south dip in the cross-bedded sandstones be disregarded, the attitude of the cliff-forming limestone is an indication of an east-west flexure on the north shore of Van. It is entirely possible that a fault exists at this place.

OIL INDICATIONS

Approximately 4 kilometers south of the village of Korzut three shallow wells have been drilled, and from these oil has been obtained by the Russians and others. It is credibly reported that the Russians extracted sufficient oil to run two small vessels on the lake. One of the wells has a 6-inch pipe line and the others are ordinary wells 1 meter square. They are all closed now. The report from reliable sources is that they have gone to a depth of 13 meters into a conglomerate. These wells are within 20 meters of one another. Here a small quantity of oil may be extracted locally by sinking a well and tunnelling across to the creek.

A seep is found approximately 2,100 meters (6,888 feet) northeast of Chakir Bey on the south bank of Zeylan Dere. This seep is generally covered with water, but the time of the writer's visit (August 11, 1930) happened to be the driest month in an exceptionally dry year. A definite petroleum odor was noticed, and oil was seen exuding in a small stream. The locality is entirely surrounded by syenites and basic igneous rocks.

SIVAS

A few days were spent at Sivas and a hurried trip was made to Kayseri (Fig. 9), thence to Yozgat, Chorum, and Havza, with the thought of seeing the general possibilities of the area.

All around Sivas, gypsum is found in great quantities. It was reported during 1914 that oil was found at the edge of the town opposite Abdulvahap Gazi. At present there is no sign of it, and it seems to have been a false report. The nearest to an oil indication is a hydrogen sulphide spring south of the village of Seyfi. It was said to be associated with water and mud. But at the time of the writer's visit it was dry. A decidedly strong H_2S odor emanated from the hole. It was reported

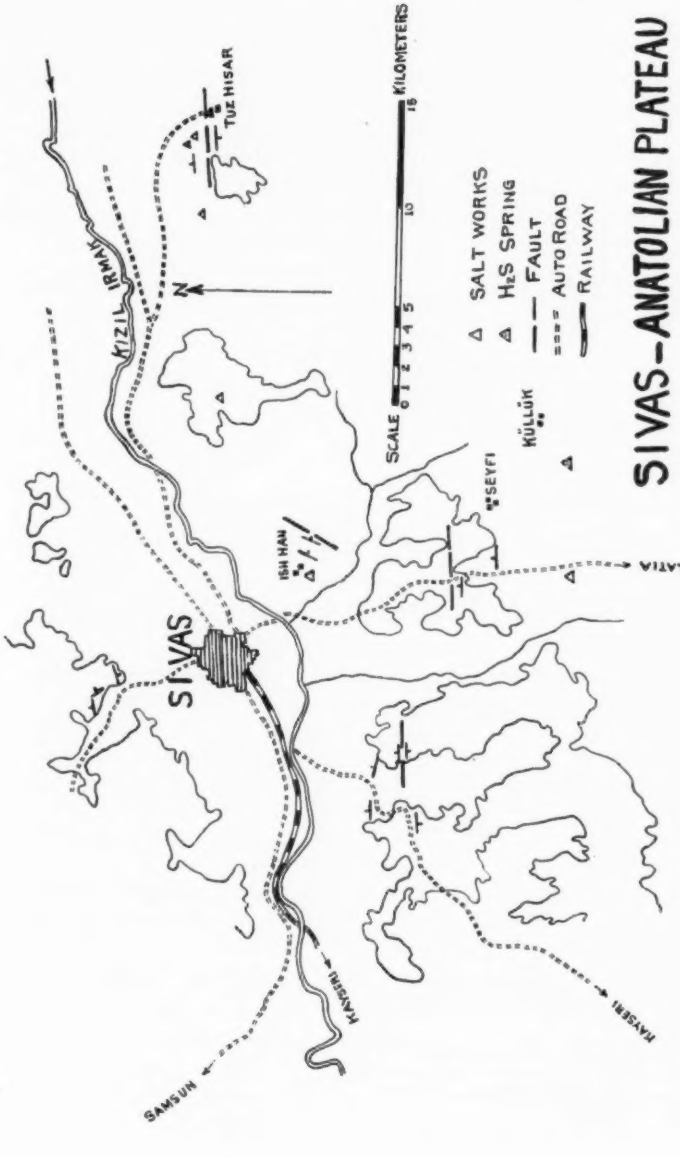

SIVAS-ANATOLIAN PLATEAU
SIVAS
KIZIL IRMAK
TUZ HISAR
ISH HAN
SEYFI
KÜLLÜK
N
SCALE 0 1 2 3 4 5 10 15 KILOMETERS
SALT WORKS
H_2S SPRING
FAULT
AUTO ROAD
RAILWAY
SAMSUN
KAYSERI
KAYSERI
MALATIA

Fig. 9

that birds flying over the spot fell dead; several bird carcasses were seen at the place. As additional indirect indication might be cited several salt-water springs from which large quantities of salt are extracted annually. One is at Mardabash, 5 kilometers west of this H_2S locality. It is nearly on the highway from Sivas to Malatia, at a place 18 kilometers south of Sivas. There is another large salt-water spring at Ish Han approximately 3 kilometers southeast of Sivas. There are rock-salt mines at Tuz Hisar, 30 kilometers east of Sivas.

STRATIGRAPHY

At Ish Han the following section is exposed, from top to bottom. The beds strike N. 10° E.

White crystalline limestone with angular fracture	
Fossiliferous white marly limestone (bryozoans, pectens, gastropods, et cetera)	
Fault	
Red conglomerate and sandstone	100 meters
Gray and pink shales	40 meters
Gypsum	5 meters
Gray and pink shales and sandstones	
Dark gray shales	

The limestone which is on top of the hill has a decidedly variable position and is believed to have been brought up by an overthrust.

From Mardabash salt works north toward Sivas one finds the following.

Crystalline limestone	
Fault	
Pink shales with gypsum	
Reddish and grayish conglomerates and sandstones with a small amount of shale	350 meters

Twelve kilometers east of Sivas, on the road to Tuz Hisar, thick red sandstones and conglomerates underlie massive gypsum with a transition series of shales and gypsum between.

Fifteen kilometers from Sivas, on the road to Kayseri, red and gray conglomerates and sandstones are overlain by pink shales and gypsum. Above this gypsum are dark gray shales.

The study of these sections seems to indicate that the normal stratigraphic sequence is as follows.

1. Gray shales without gypsum
2. Gypsiferous pink and gray shales
3. Red conglomerates and sandstones
4. Limestone

STRUCTURE

There is much faulting in the area. Though most of the faults are normal, there are several thrust faults. Southwest of Sivas there is an anticlinal structure shown in the red conglomerate and sandstone. The anticline is faulted near its crest.

At the Tuz Hisar, where rock salt occurs, the beds are vertical or almost vertical. At Ish Han, where the limestone has come to the top through an overthrust, the dips are approximately 50°.

Even the Quaternary conglomerate and gravel covering the hills on the north are tilted, indicating that the region has undergone a succession of earth movements continuing until very recent time.

Miscellaneous Coastal

Under this heading widely scattered regions at or near the coast are discussed. These regions are (1) Murefte, (2) Chirali, (3) Boyabat, and (4) Mapavri.

MUREFTE

This region is on the north shore of Marmora, 80 miles southwest of Istanbul. The rise from the sea to the top of the Eocene hills is abrupt. Mount Elie, at an elevation of 680 meters (2,230 feet), is only 5 kilometers from the shore. The hills north of Ganos which make an escarpment along Marmora are higher, attaining elevations of more than 800 meters (2,624 feet). Therefore, the topography from the hills to the shore is almost precipitous. Although toward the south in the vicinity of Sharkoy the declivity is gentler, the hills there attain an elevation of 300 meters in less than 5 kilometers. The range of hills thus enclosing the crescent-shaped area is known as Tekir Dag range, the peaks having individual local names. The creeks, which are in their youth, erode the land very rapidly, causing deep chasms and broken topography. This area suffers from landslides caused by the argillaceous character of the soil, by a steep seaward gradient, and by tectonic processes which are still alive. The drainage is to Marmora, and the creeks flow during the whole year.

STRATIGRAPHY

Pleistocene and Recent.—A very thin belt of coastal deposits along the fringe of the sea and poorly consolidated coarse conglomerate along the various creeks are in this classification. Their maximum thickness is 15 meters.

Pliocene.—On the top of hills on the left bank of Hora Dere a shelly limestone is encountered to which the Pliocene age is assigned. The for-

mation, which contains numerous broken fossils, was observed only at this locality. Even if it is found at the high places on some hills not visited, the extent must be limited.

Miocene.—Underlying the formation mentioned in the preceding paragraph and at the top of the Miocene section is a persistent cross-bedded sandstone to which the name Palatina sandstone is given. At the village of Palatina, north of Murefte, its thickness is estimated to be not less than 100 meters. This sandstone is fine- to medium coarse-grained and is characterized by much jointing, cross-bedding, and a poor state of consolidation. It is evidently a continental deposit and few of its dips can be relied on.

Below the Palatina sandstone a pink marly shale, 20 meters in thickness, is exposed around Murefte locally, but is not sufficiently well developed to be considered as more than a mere tongue in the sandstone group.

Underlying these shales a sandstone characterized by its concretions, in many places as large as 1 meter in diameter, is found. The concretions are hard, though not compact in many places, and appear like phenocrysts in a groundmass of poorly consolidated sands. Toward the base the formation is distinctly lignitic. The seams are approximately 10-30 centimeters thick. The concretionary sandstone is much better developed in the Sharkoy area than in the Murefte region. However, even at Murefte it has a thickness of approximately 60 meters. In the region near Sharkoy the thickness of these concretionary sandstones is not less than 300 meters. It probably also represents the Palatina sandstone.

Below the sandstone group are the variegated shales, with a thickness of 50-100 meters. The relation between these shales and the overlying sandstone group is believed to be conformable, though locally a thin bed of conglomerate is observed to overlie the shales and underlie the sandstone. The paper-thin shales of the Sharkoy region may be correlated with these, though the surface relationship is not evident because of faulting.

Eocene.—Dark gray shales with conchoidal fracture and hard sandstone layers 25-35 centimeters thick characterize the underlying formation. Though the assignment of Eocene age to these shales is arbitrary, it is evident that they are older than Miocene. Unfortunately, satisfactory relations between these dark shales and the overlying varicolored shales has not been observed. Below the dark gray shales is a limestone containing ***Lepidocyclina*, *Nummulites*, *Operculina*** and other foraminiferal forms. On the road from Yayakoy to Palatina approximately 450 meters

(1,476 feet) of these shales is exposed. However, the dips are so steep, at places overturned, that duplication is easily possible. On the same road a thin bed of conglomerate is found separating the shales from the foraminiferal limestone.

In Arably Canyon, northeast of Sharkoy, a very strong development of a conglomerate underlying these shales is observed. The thickness of this conglomerate is not less than 200 meters. Both the dark gray shales and the underlying conglomerate are characterized by very steep dips.

Mount Elie limestone.—A massive, amorphous, very hard siliceous limestone is exposed on Mount Elie, which is referred to as Mount Elie limestone. Its age is a matter of conjecture. It is seen to underlie the varicolored shales at a strong fold in the western end of Mount Elie. But, as noted in the structural discussion, in a region so broken and distorted, relations observed only through faulting can not be relied on.

STRUCTURE

The region is evidently in an active zone of diastrophism. This is indicated not only by the exceptional character and great number of landslides, but also, very definitely, by the recent earthquakes which devastated the area under discussion prior to the World War and other seismic movements which have occurred in the region before and since that time. The structural history of the region seems to be as follows.

1. It is quite clear that the beds referred to as the Eocene shales have experienced more folding than the Miocene. Therefore, over an already folded Eocene were deposited the various Miocene formations described. Thus, there is a post-Eocene and pre-Miocene folding.

2. This folding was followed by the deposition of Miocene shales and sandstones.

3. Then the Miocene strata became folded, giving rise to certain anticlines referred to as the Hora and Murefte anticlines. This probably occurred during the Pliocene.

4. After this, the region experienced severe diastrophism, which brought the Eocene to high elevations and broke it, along an extensive zone from Ganos to Sharkoy, in a zigzag fashion.

OIL INDICATIONS AND DEVELOPMENT

At the junction of two creeks, 4 kilometers upstream from the confluence of Hora Dere with Marmora, a well was drilled about 1890. It is reliably reported that for a few days oil was obtained at shallow depth (100 meters) at the rate of 2 tons per day. The well soon ceased to be

productive and was abandoned. There is evidence that at least some oil was obtained from the old well. The writer was unable to verify other alleged indications.

Besides the well mentioned in the foregoing paragraph, it is reported that another hole was sunk to a depth of 400 meters within a kilometer and near the steeply dipping Eocene beds, according to an alleged letter written by the driller working on the location. There is good reason to believe that some work was done near this place. Whether the hole actually reached a depth of 400 meters is not known, but it is certain that it yielded no production. The location is on the top of vertical Eocene beds and obviously nothing should be expected. Later, in 1914, some efforts were made by a Pole, but these naturally stopped with the war. Still later, Khedive built roads at both Murefte and Hora and sank some large shallow holes in the river conglomerate as a pretense at complying with the regulations.

CHIRALI

At Chirali, 40 miles south of Anatalia and 25 miles east of Finike, on the southern shores of Asia Minor on the Mediterranean, within less than a mile of the sea, is found an ancient temple which is in ruins, but the flames for which it was originally erected 2,500 years ago continue to burn. From two orifices the flames rise 40 centimeters above the ground. It seems evident that other orifices formerly existed. Both the temple and the gas seepage are near the contact between the large serpentine mass and a massive limestone. The region is subject to earth movements, and undoubtedly the friction of rock against rock during one of the movements ignited the issuing gas.

This region has a mild winter climate. Oranges and cotton are raised in abundance.

STRATIGRAPHY

Post-Eocene.—Cochinal limestone, which at places (Karabel, 25 miles northwest of Finike) contains dry asphalt in its interstices, is seemingly younger than the Eocene limestone covering the region.

Eocene—At Salir Dag, on the road from Kumluje to Finike, as well as on Alaja Dag (north of Gulmez) on the road from Sazak to Chagman, a massive foraminiferal limestone containing many *Nummulites* and some corals is found which is referred to the Eocene. On the road to Chagman it is characterized by a well developed cleavage system which through erosion makes vertical ledges, giving at first a false impression of vertical bedding. It contains angular chert pebbles, rectangular

sandstone fragments, and a few boulders. This brecciated member is in the lower part of the formation. Its thickness can not easily be estimated, but it is probably approximately 100 meters.

Cretaceous.—Underlying the foregoing is a non-cherty bluish gray limestone with porcelain-like fracture, which is particularly well developed at Finike. It is well stratified, with individual beds ranging from 8 to 36 inches in thickness. At Finike the estimated thickness is 150 meters. The assignment of Cretaceous age is arbitrary, but its stratigraphic position is between the Nummulitic limestone and the thin-bedded limestone with *Inoceramus*. The absence of the chert nodules is characteristic of the Finike limestone.

The massive cherty limestone of the Chirali region underlies the Finike limestone. Evidence of this is obtained on the road from Beg Melek to Finike. It is light gray in color, massive in the center, thin-bedded near the top and near the base, and almost pure $CaCO_3$. It contains chert inclusions in profusion. On the road from Kumluje to Chirali, at the saddle of Shapsal Dag, the writer found an *Inoceramus* which would give these limestones an Upper Cretaceous appearance. Chert is present in the massive as well as in the thin-bedded parts. The total thickness of this limestone is 300-500 meters.

Underlying the limestone is a yellowish brown sandstone with characteristic hard layers. This sandstone is exposed near the village of Belen at Shapsal Dag and on the road from Belen to Chirali. It is not very thick, perhaps less than 50 meters.

The red beds that underlie the sandstone mentioned are principally shales with thin layers of indurated limestone. The limestone is flinty. Red coloring is the result of its association with basic igneous sills which intrude these shales and the thin-bedded limestones.

The section may be summarized as follows.

	Thickness in Meters
1. Cochinal limestone	50–100
2. Nummulitic limestone	100
3. Finike limestone	150
4. Massive cherty limestone	250
5. Thin-bedded limestone	150
6. Yellowish brown sandstone	30
7. Gray and red shales	

Igneous.—The region of Kumluje to Chirali shows much evidence of igneous activity. Huge serpentine masses and many basaltic sills are found associated with the limestones and the red beds of the region. One

of these masses in contact with the limestone gives rise to the gas seepage and the consequent eternal fire at Chirali. The igneous activity is incidental to the faulting and folding which occurred during the late Tertiary.

STRUCTURE

The outstanding structural pattern is north-south. The mountains of the region with north-south trend seem to be the result of secondary movements associated with the tectonics of the Taurus Range, which extends approximately east and west.

More or less continuous deposition occurred during the Middle and Upper Cretaceous, extending into the early Tertiary. Then a series of earth movements began in this region, which culminated during the late Tertiary in large faults, raising mountains like Tahtali to great heights. The fault plane incidental in these tectonics became channels for igneous activity, permitting huge masses of serpentine and many basaltic sills to intrude the limestone and the shales.

The eastern part of the area (Markiz Dag, Musa Dag, and Tahtali Dag) has suffered much severer stresses than the western. Whereas the foregoing are fault blocks, the mountains on the west (Touchak Dag and Gulmez Dag) are ordinary anticlines rising progressively higher northward.

From Finike to Elmaly the shales and the sandstones are much distorted. The limestones overlying them show only moderate dips. The situation suggests a decided disconformity between the two. However, the writer's personal belief is that the effect of the tectonics on soft pliable shales differed from the effect on a competent and massive limestone.

BOYABAT

Boyabat is 60 miles south of the port of Sinop on the Black Sea. In an air line it is not more than 80 kilometers. It is connected with Sinop by an automobile road which is open at all times except when snow covers the pass during winter. From Sinop one climbs to an elevation of 1,030 meters (3,400 feet) before descending into the graben of Geuk Su Valley at the south side of which the town of Boyabat is located. The region has plenty of water and contains important rice-producing fields.

STRATIGRAPHY

Paleozoic.—At the edge of the town of Boyabat the greenish indurated shales with quartz veins which are exposed are referred to the Paleozoic. Coming from Vezirkopru one observes these rocks following

the banks of Kizil Irmak. They are probably very thick. Associated with it and seemingly younger are the serpentines at Boyabat as well as along Kizil Irmak.

Cretaceous.—Hard bluish gray cliff-forming limestones on Juma Aksham Dag and other places are found overlying the indurated Paleozoic shales. They contain ***Hippurites*** and are referred to the Cretaceous. M. Lucius has found evidences of Cretaceous age in the gray shales in the Ekin Viren Yayla on the north.

Eocene.—The foraminiferal limestone of Boyabat occurring at the fortress and continuing at Ak Yuruk and beyond are tentatively referred to the Eocene. This is a massive white limestone, almost pure $CaCO_3$. At Kaz Dere, west of Boyabat, at the base of this limestone, is seen a conglomerate 3 meters thick. Below the conglomerate are the metamorphosed Paleozoic shales and the serpentine. The section above the conglomerate is approximately 30 meters of yellowish calcareous marls. These grade upward into well bedded limestones, then into the white crystalline and massive limestone forming the base of the old fortress. The section from the conglomerate up is more than 100 meters. The nummulitic phase is observed on the road between Kuru Saray and Ak Yuruk.

The section exposed at Maruf Dere from a little north of the seepage to a kilometer south of Maruf village is referred to the Eocene without any fossil evidence. Both Shirley L. Mason and M. Lucius, in their reports, consider this section Eocene. In the absence of evidence to the contrary and in order not to cause unnecessary confusion, the writer refers to the Maruf Dere section as Eocene. The section is composed of beds ranging in dips from 70° to 100°. It is much folded and faulted. The section is composed of the following.

1. Coarse clastic limestone approximately 50 meters thick. Above the base it contains prominently inclusions of black shales.

2. Sandstones and black slaty shales. The seepage occurs in this group.

3. Gray slaty calcite-veined hard shales interbedded with soft black shales. Some members contain hard calc-siliceous nodules. The thickness of groups 2 and 3 is approximately 125 meters.

4. Gray sandstones and fine-textured conglomerates, 125 meters.

5. Gray shales with thin sandstone layers. It is difficult to estimate the thickness because of great lithologic similarity and certain repetition of beds, but it must be approximately 500 meters. Therefore, the Maruf Dere section has a minimum total thickness of 800 meters. Formation

5 is undoubtedly younger than the rest and is referred to the Oligocene by Mason.

Pliocene.—Overlying the Maruf Dere section with a pronounced unconformity are thick and rather gently dipping sandstones and conglomerates. These are cross-bedded, less consolidated, and generally coarse. Their thickness is not less than 1,000 meters.

Quaternary and Recent.—The basalt flows seen near Ak Yuruk west of Boyabat are believed to be early Quaternary. Silts and gravel of Geuk Irmak valley are recent fluviatile deposits laid down since the latest movement.

STRUCTURE

Faulting is the predominant note in the structural scheme. The area between Boyabat and Ekin Viren where the seepage occurs is a definite down-thrown valley. The beds and the major faulting have an approximately east-west trend following the coast range and the coast. Evidently the region has suffered violent disturbances until recently. Even the early Quaternary has seen activity in the form of basaltic eruptions. The movement since the Paleozoic must total thousands of meters with the Paleozoic occupying fairly high mountains on both sides of the valley and the Pliocene deposits, stratigraphically 2,000 meters higher, in the valley between at a lower elevation. Obviously, with such intensity of tectonics, most of the beds have assumed very steep attitudes, 75° or more, and no ordinary anticline exists or may be expected. The area presents interesting comparison with Pechelbronn and Rhine Valley graben.

OIL INDICATIONS

A few hundred meters north of Ekin Viren in Maruf Creek, high-grade paraffine-base oil seeps from one of the many faults of the graben area. The seep is probably a local distillation product of the black shales and does not represent a seepage from an oil reservoir.

MAPAVRI

Mapavri is a good-sized village situated 20 kilometers east of Rize on the Black Sea. Rize itself is 553 miles from Istanbul. Precipitous mountains skirt the coast here as they do the greater part of the Turkish Black Sea coast. The region is well supplied with water, and though the tillable ground is scarce because of the mountainous character of the region, it is very fertile. A good picturesque automobile road connects it with Rize and Trabzon.

STRATIGRAPHY

Except for a narrow strip of sandstones and conglomerates of recent date along the coast, the region is covered with dark igneous rocks most of which are effusive in character. Evidently there were several periods of igneous activity. The most recent "flows" brought along with them good-sized igneous rocks which apparantly formed the path. The earth movements of the region have been active until very recently. The basaltic flows of the late Tertiary, as well as the more recent conglomerates, have been faulted by later movements.

OIL INDICATIONS

Oil seeps from the bottom of the sea at a point N. 45° W. from Mapavri, approximately 3½ kilometers from the shore opposite the mouth of Kible Creek. The depth from the place where gas bubbles and oil emanate has been measured and found to be 63 fathoms. The oil is believed to issue from a fault in the bottom of the sea. Small samples may be gathered in calm weather, by patient work. No information can be obtained concerning the sedimentary rocks below.

NATURAL GAS FROM ORISKANY FORMATION IN CENTRAL NEW YORK AND NORTHERN PENNSYLVANIA[1]

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ABSTRACT

The recent discovery of two large gas fields producing from the Oriskany formation has been responsible for much leasing and drilling activity in central New York and northern Pennsylvania. The geologic section consists of an almost complete series of Devonian rocks, which, because of the general southwest dip, are all exposed from the outlets of Seneca and Cayuga lakes to the Pennsylvania state line. The Devonian section of this region is plentifully supplied with black bituminous shales, but the lack of suitable reservoir rocks has probably been the cause of the comparatively restricted area in which gas is produced from these rocks. The Oriskany sandstone, which is the producing horizon of both the Tyrone and Farmington fields, is a very erratic formation because of extraordinary conditions of deposition. It is the basal Devonian formation throughout the greater part of central New York, but it overlaps progressively older formations westward from the Hudson Valley. The folds of the area, in general, parallel the great mountain folds of central Pennsylvania, but the structures of central New York are regarded as *en échelon* folds which are due to a change in the direction of strike of the main system of folding. Most of the structures are believed to be the surface expression of underthrust faults. Closures occur along the anticlines where the direction of strike locally changes and where the Appalachian folds intersect the axes of what is believed to be an Ordovician system of folding. Other gas fields may be expected from the Oriskany, but the success of exploratory drilling will depend not only on the location of favorable structures, but also on the occurrence of the sandstone.

INTRODUCTION

The discovery of the Tyrone field, located in Schuyler County, New York, in March, 1930, and the Farmington field, located in Tioga County, Pennsylvania, in September, 1930, both producing from what is believed to be the Oriskany sandstone, has been the cause of unparalleled leasing and drilling activity in central New York and northern Pennsylvania. Prior to these discoveries many test wells had been drilled in this region through the Oriskany horizon, in prospecting for, and in the production of, salt, without commercial gas fields being found. For this reason the writer has prepared this paper with the idea of attempting to establish some of the factors which were involved in the location of the discovery wells in these fields and of describing their de-

[1]Manuscript received, March 3, 1931.

[2]Torrey, Fralich, and Simmons, geologists and petroleum engineers.

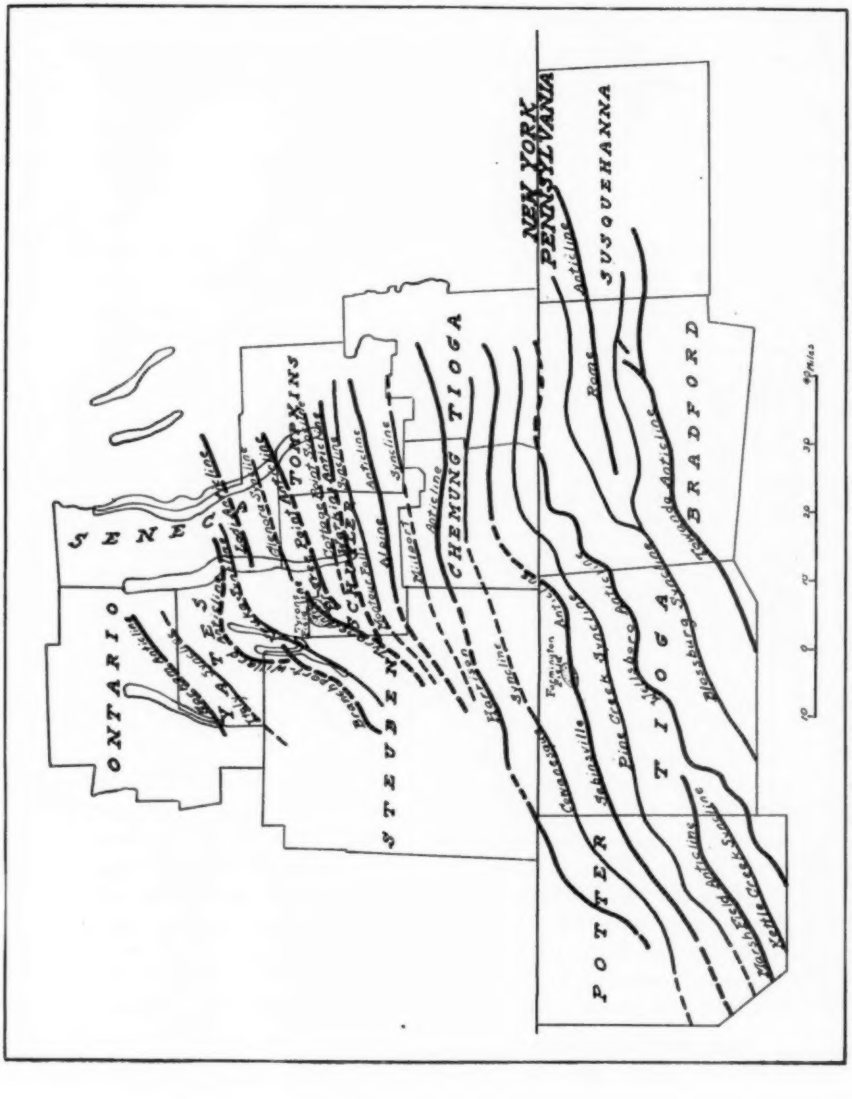

FIG. 1.—Map showing location of Tyrone field in south-central New York and Farmington field in northern Pennsylvania, and position of the more prominent structural axes in this region.

velopment to the present. The location of the Tyrone and Farmington fields is indicated in Figure 1, which also shows the approximate position of some of the more important structural axes.

GENERAL STRATIGRAPHY

GEOLOGIC SECTION

Most of the rocks cropping out in this region and those encountered by drilling are of Devonian age. Because of the general south and southwest dip of the strata northward from Tioga County, Pennsylvania, progressively older beds are encountered at the outcrop, so that it is possible to examine almost the entire section of Devonian rocks from the Pennsylvania line to the outlets of Seneca and Cayuga lakes. Lower Carboniferous rocks occur in the synclines of Tioga and Bradford counties, Pennsylvania, and all of the salt wells and a few other deep test wells have been drilled into strata of upper Silurian age in the Finger Lakes region. The many excellent exposures of Devonian rocks along the shores of the lakes and in the adjacent ravines have been the object of intensive study from the time of the earlier geological investigations. The columnar section of Devonian rocks shown in Figure 2 is based on measurements of the thickness of many of these outcrops, which have been more fully described by Hall,[1] Vanuxem,[2] Clarke,[3] Luther,[4], Lincoln,[5] and by the United States Geological Survey.[6]

This section must be accepted as being somewhat generalized, not only because the Devonian rocks thicken toward the east, but also be-

[1]James Hall, "The Fourth Geological District," *Mem. New York State Mus.*, Vol. 4, Pt. 4 (1843).

[2]Lardner Vanuxem, "The Third Geological District," *Mem. New York State Mus.*, Vol. 3, Pt. 3 (1842).

[3]J. M. Clarke, "Stratigraphy of Canandaigua and Naples Quadrangles," *New York State Mus., Bull. 63* (1904); J. M. Clarke and D. D. Luther, "Watkins and Elmira Quadrangles," *New York State Mus. Bull. 81* (1905); "Geologic Maps and Descriptions of the Portage and Nunda Quadrangles Including a Map of Letchworth Park," *New York State Mus. Bull. 118* (1908).

[4]D. D. Luther, "Geology of the Penn Yan-Hammondsport Quadrangles," *New York State Mus. Bull. 101* (1906); "Geology of the Geneva-Ovid Quadrangles," *New York State Mus. Bull. 128* (1909); "Geology of the Auburn-Genoa Quadrangles," *New York State Mus. Bull. 137* (1910).

[5]D. F. Lincoln, "Report on the Structural and Economic Geology of Seneca County," *New York State Mus., Rept. of State Geologist*, pp. 60-125 (1894).

[6]"Geologic Atlas of the United States," *U. S. Geol. Survey, Watkins-Catatonk Folio 169.*

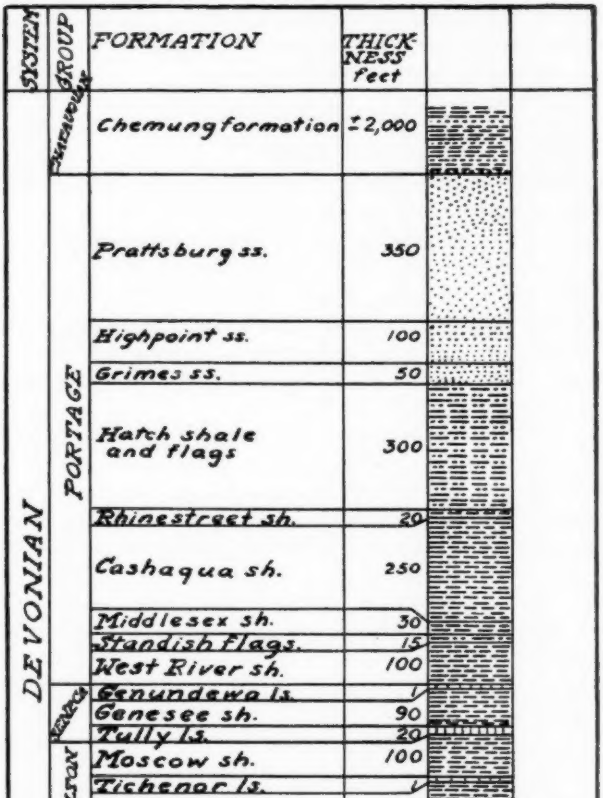

FIG. 2.—Columnar section of Devonian rocks cropping out in central New York.

cause the beds of the Portage group begin to change in lithology and in fossil faunas from the typical Naples section to the Ithaca section between Seneca and Cayuga lakes. This transition is, in itself, an involved problem of the stratigraphy of New York state and has been comprehensively described by Clarke.[1] The cross section shown in Figure 3 is essentially the same as the one used by Clarke to illustrate the changing character of the Portage beds.

It is evident from these sections that in this region the Upper and Middle Devonian rocks are fully developed and that many of the important Lower Devonian formations which occur in eastern New York are entirely missing. Most of the Devonian rocks represent an almost continuous record of sedimentation except in the basal formations, where, in central New York, there is a very important stratigraphic unconformity.

SOURCE BEDS

The New York Devonian section is well supplied with source beds. Black, carbonaceous, and bituminous shales are common. In the Portage group there are the Rhinestreet, Middlesex, and West River shales, and in addition some carbonaceous shales are found in the Cashaqua shale and in the Hatch and West Hill flags. The Genesee shale is very bituminous, and the Hamilton beds contain organic remains in profusion. Both the Cardiff and Marcellus shales are uniformly bituminous; the underlying Onondaga limestone contains asphaltic residue at several localities; and in some places liquid hydrocarbons have been found in Onondaga corals. The New York Devonian section is, therefore, amply supplied with possible source beds, but the lack of suitable reservoir rocks has undoubtedly been the cause of the comparatively restricted area in which gas is produced from Devonian rocks.

RESERVOIR ROCKS

Oriskany sandstone.—The Oriskany sandstone, which is believed to be the producing horizon of both the Tyrone and the Farmington fields, is either the basal Devonian formation throughout central New York or it is separated from the Silurian by only a few feet of Helderberg limestone. At the outcrop, the Oriskany is a very erratic formation. In order to understand better the characteristics of its occurrence, a brief outline is here given of the geologic history of the changes in conditions of sedimentation that were responsible for its deposition.

[1] J. M. Clarke, "Naples Fauna in Western New York," *New York State Mus. Mem. 6*, Pt. 2, pp. 199-214.

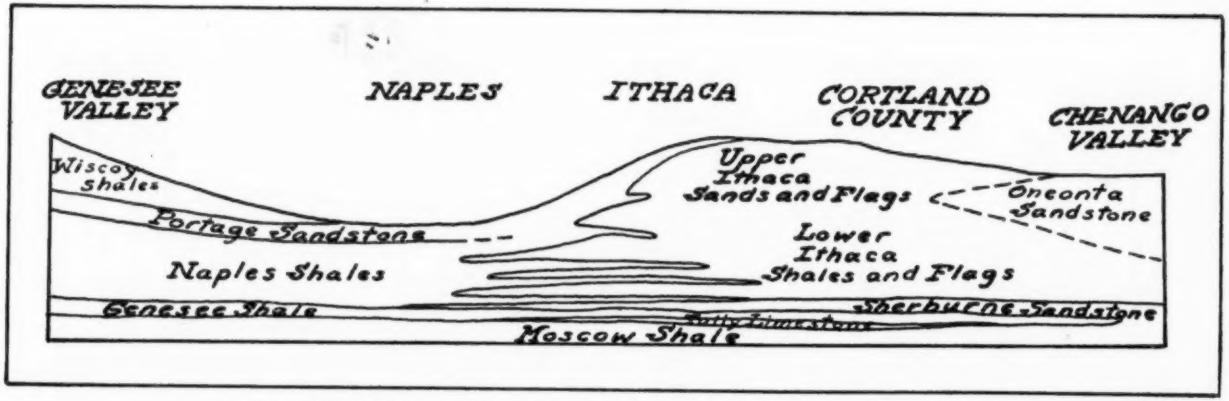

FIG. 3.—Generalized cross section of Portage rocks from Genesee Valley to Chenango Valley.

At the close of the Silurian there was a constriction of the sea toward the east, accompanied by a general elevation of the area that is now western New York. This elevation continued until the only remnants of the once widespread Silurian sea existed in a long narrow trough approximately paralleling the continental land mass on the east. In this sea the Helderberg limestones were formed, and during the period of their deposition much of western and parts of central New York were subject to active erosion. Following this period of sedimentation there was seemingly an elevation of the land mass on the east which brought down into the sea much sandy material and which also affected the depth, area, and outline of the water. These sandy deposits compose the Oriskany formation, and as the sea in which it was formed advanced toward the west or in effect was pushed across by the rising eastern continental mass, the sandstone was laid down on successively older formations which had been uncovered by erosion during the time that the limestones of the Helderberg group were being formed in eastern New York. The first deposits of the Oriskany were confined to a small part of the old Helderberg sea, and as the water transgressed toward the west a condition of progressive overlap was established. Along the Hudson Valley the Oriskany rests on the Port Ewen limestone, the highest member of the Helderberg group; in the Schoharie Valley it rests on the Becraft; in Herkimer County it rests on the Coeymans; in Cayuga County, on the Manlius; in Erie County, on the Cobleskill; and in southern Ontario the Oriskany horizon is reported to be immediately above the Bertie. During the later stages of its deposition the formation of the Esopus shale and Schoharie grit was in progress in eastern New York. These beds have only a limited extent because continued subsidence of the ocean basin resulted in the last great cycle of Paleozoic limestone deposition, during which time the Onondaga limestone was laid down.

The Oriskany sandstone, where best developed on the outcrop, is a fairly coarse-grained, cream-colored, somewhat loosely cemented sandstone. A few small quartz pebbles occur here and there in the lower beds, and small, flattened nodules of chert are found in places. In the upper part of the formation at certain localities there are numerous dark-colored or almost black, calcareous concretions. At some weathered exposures, these concretions almost cover the surface of the ground long after the sandstone has disintegrated. At the outcrop and from samples obtained from wells, the chief cementing material is calcite, although some siliceous cement is present. In the eastern part of New

York the formation is so calcareous that it could properly be designated a sandy limestone. The Oriskany is very fossiliferous, but because of the size of the sand grains the fossils are rather poorly preserved except in unweathered exposures. Bedding planes are ordinarily somewhat indistinct, and generally the sandstone appears to be massive. However, notable examples of cross-bedding are found at some localities.

Because of somewhat exceptional conditions of sedimentation, in comparison with the other Devonian beds, and the probable rapid westward transgression of the sea in which it was deposited, the occurrence of the Oriskany, both at the outcrop and as established by drilling, is extremely variable. It is probably the least continuous of any of the Devonian rocks, and at many localities its position in the section can only be inferred between the Onondaga limestone and the underlying Helderberg or Silurian limestones. At the type locality it can not be followed for any great distance, and west of this place typical outcrops are rare. The Oriskany, as developed in central and western New York, probably represents submarine bars which were not subject to swift ocean currents or which mark the shore line of the sea during a temporary suspension in the advance of the water. Elsewhere the transgression of the sea was seemingly so rapid that accumulations of sand did not occur, or if formed they were removed and washed away by subsequent changes in the position and outlines of the sea.

Therefore, it seems evident that careful studies of Oriskany sedimentation are as essential to the successful location of new gas fields as the mapping of the anticlinal structures.

STRUCTURE

HISTORY

In general, the rocks of New York and northern Pennsylvania, from Lake Erie on the west to the Hudson Valley on the east, dip toward the southwest. This dip is in part due to depositional conditions, but the succession of elevations and depressions which controlled the formation and distribution of the Paleozoic rocks were an important contributing factor. Four important periods of structural deformation are evident: (1) at the close of the Ordovician, (2) during the Devonian, (3) during the Mississippian, and (4) at the end of the Paleozoic. In addition, parts of eastern New York were undoubtedly affected by the disturbances occurring during the Triassic, and both New York and northern Pennsylvania were subject to the elevating movements which occurred during the Cretaceous and Tertiary.

At the close of the Ordovician, the strata of eastern New York and western New England were subjected to a somewhat violent period of mountain building which has been designated the Green Mountain disturbance. The effects of this disturbance are evident in the Hudson Valley, where the Silurian beds rest unconformably on folded and faulted Ordovician rocks. Prior to the Green Mountain disturbance, and in fact during most of Ordovician time, the subsidences within the geosynclines had warped the bottoms of the continental seas and affected their depth, area, and outline. The emergence of the Nashville-Cincinnati islands which originated in Tennessee during the Middle Ordovician probably had only a minor effect on the Ordovician rocks of western New York, but undoubtedly it was partly responsible for the movement in centers of sedimentation which marked the beginning of Silurian time, and it served to accentuate the compressive effects on the strata of central New York. In central New York and northern Pennsylvania the direct effects of these disturbances are not so evident, because of the thick covering of rocks over the Ordovician beds, but it is very probable that axes of folding were established which had a decided influence on the position of folds found in the present outcropping rocks. The general direction of strike of the Ordovician deformation seems to have been more nearly north and south than the subsequent period of elevation and mountain building which marked the close of the Paleozoic.

During early Devonian time, the eastern boundary of the Appalachian sea was gradually elevated with a tilting effect which pushed the Oriskany sea across New York state. This movement merely tended to shift again the centers of sedimentation, and it was not accompanied by any well defined structural deformation. However, during Middle Devonian and continuing through Upper Devonian time, the rocks of New England and the maritime provinces of Canada were again elevated and folded, resulting in a recurrence of active erosion from which the arenaceous deposits of the Portage, Chemung, and Catskill formations were derived. This movement, which very probably tended to establish further the lines of deformation which originated in the Ordovician, has been designated the Shickshockian disturbance.

During the Mississippian, there is evidence of a decided tilting movement toward the south and southwest which prevented the northern invasion of the Carboniferous seas and which tended to establish better the southward migration of centers of sedimentation.

At the close of the Paleozoic, much of eastern North America was folded, faulted, and thrust toward the west and northwest, and these

earth movements superimposed a series of folds on the tilted and otherwise gently deformed strata of central New York and northern Pennsylvania.

DESCRIPTION OF STRUCTURES

The position of the axes of the more important anticlines and synclines in central New York and northern Pennsylvania are shown in Figure 1. Almost all of these folds parallel the structures of the Appalachian mountain system, but most of them differ in form from the typical Appalachian folds.

Beginning in the southeastern corner of Cattaraugus County and extending in a general but not continuous northeasterly direction, the Appalachian system of folds is found superimposed on the gently southwest-dipping strata. This direction of strike is maintained through Allegany, Steuben, Ontario, Yates, and Schuyler counties, but beyond the longitude of Seneca Lake the strike changes to an almost due east direction. At the place where the direction of strike definitely changes, the strata are generally somewhat badly disturbed. An excellent example of this may be seen along the axis of the Sabinsville anticline southwest of Elmira. Where the folds of the Appalachian system intersect the axes of the much older north-south system of folding, domes of considerable size are generally found, such as the Branchport and Gorham domes in Yates County, the Tyrone dome in Schuyler County, and the Ludlowville dome in Tompkins County. Farther south, along the better defined folds which are nearer the centers of Appalachian deformation, there is much less evidence of the existence of the older Ordovician system of folding. Most folds of the Appalachian system extend long distances, and they are characterized by changes in direction of strike at short intervals. At such places local closures are almost invariably found. These closures are separated by saddles or re-entrant synclines which in northern Pennsylvania strike approximately N. 70° W.

The folds of the Appalachian system are characterized by a gentle north and northwest dip and a much more pronounced south and southeast dip. Ordinarily, approximately 1 mile south or southeast of the axes of the folds there is an area of very pronounced dip which rarely extends more than 2,000 feet. This structural feature is in contrast with the most common type of Appalachian folding, where the steeper dips are found on the northwest side of the structure or on the side farthest removed from the center of deforming activity. These steep dips can not be attributed to a combination of regional and structural dip, for all of the anticlines plunge southwestward, in the direction of the re-

gional dip. It is, therefore, believed that they are the surface expression of powerful underthrusting effects in the lower beds, because if the folds were the result of overthrusting, the steepest dips should occur along the northwest flank, that is, on the side of the anticline away from the origin of the earth movement. It is impossible to state at the present time how high into the sedimentary rocks these faults extend, but it is logical to believe that they are more or less restricted to the lower Paleozoic strata. It is the writer's opinion that the Ordovician limestones were sufficiently competent to carry the weight of the overlying sediments and that the main faulting action occurred in strata below these beds. In the great anticlinal valleys, south of Susquehanna River, the Ordovician beds are folded and dip in conformity with the much younger beds outcropping stratigraphically above them.

The limited extent of the folds in the Finger Lake region in comparison with the structures in northern Pennsylvania is probably explained by the fact that these are *en échelon* folds which resulted from a general change in the direction of strike of the more pronounced folds on the south. This change in direction of strike seems to have been caused by an increase in the resistance to deformation of the Ordovician and Cambrian rocks, because of definite trends of folding, striking in an opposite direction to the typical Appalachian folds that had been previously established in them, and by variations in the competency of these beds which produced an unequal transmission of stresses through the strata. Near the end of the main system of folds, which occurs in Susquehanna County, Pennsylvania, and Tioga County, New York, these stresses were both compressive and rotational; therefore, the length and position of the central New York folds were established by a definite area of deforming activity beyond which the strata are only slightly disturbed.

TYRONE FIELD

The Tyrone field, located in the northwestern corner of Schuyler County, was discovered in March, 1930. The surface structure and the location of wells are shown in Figure 4. This structure is based on the elevations above sea-level of the Parrish limestone, a member of the Cashaqua shale. Most of the wells have their origin in the Cashaqua shale, and the average depth to the Oriskany is approximately 2,075 feet. A representative driller's well record is given in Table I. The various Naples formations of the Portage group can not be accurately identified, but the beds referred to in the log as limes are probably hard flags. The lower formations are easily recognized.

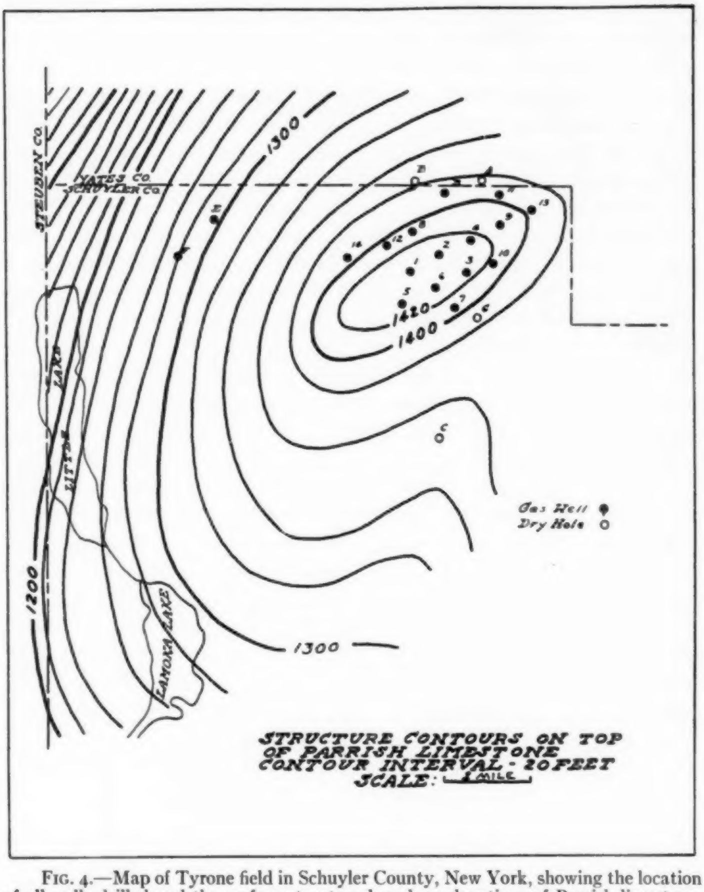

FIG. 4.—Map of Tyrone field in Schuyler County, New York, showing the location of all wells drilled and the surface structure based on elevations of Parrish limestone.

The production from Tyrone has been very satisfactory, and the initial closed-in rock pressure has been almost normal. In Table II a record of all of the wells drilled in the field is presented.

The gas from the Oriskany in the main part of the Tyrone field contains some hydrogen sulphide which is removed by a Koppers cleaner before the gas is turned into the line. The gas from the Erwin wells is

TABLE I

TYPICAL DRILLER'S WELL RECORD FOR TYRONE FIELD

State of New York, County of Schuyler, Town of Tyrone
Well No. 12. Operating Company, Belmont Quadrangle Drilling Corp.
Waddell Farm, Location, Sec. 11, T. 12, R. 30. Contractor, C. F. Goble
Spudded in, December 23, 1930. Completed, December 27, 1930. Elevation, 1,532.14 feet

Formation	*Depth in Feet*	*Remarks*	*Formation*
Surface	5	White	
Gravel	10	Yellow	
Slate	34	White	Naples shales and flags
Lime	40	White, hard	
Slate	70	White	
Sand	95	White	
Shale	108	Light	
Lime	125	White	
Shale	250	White	
Sand	260	White	
Shale	300	White	
Sand	325	White	
Shale	500	White	
Lime	518	White	
Shale	580	Brown	
Shale	660	White	
Lime	730	White	
Slate	802	White	
Lime	858	White, hard	
Shale	950	White	
Shale	1,138	Brown	
Lime	1,163	Brown, hard	
Shale	1,185	Brown	
Shale	1,343	Brown	Genesee shale
Lime	1,360	White	Tully limestone
Shale	1,460	White	Hamilton shales
Shale	1,760	Brown	Hamilton shales
Shale	1,974	White	Hamilton and Cardiff shales
Shale	1,997	Black	Marcellus shale
Lime	2,102	Black	Onondaga limestone
Sand	2,117	Steel line measurement at 1,997 feet	Oriskany sandstone

sweet and does not require treating, indicating that the sand may not be continuous between these wells and the main part of the field.

The Tyrone field was considered a very favorable area before the discovery well was drilled, because several wells previously drilled in the syncline on the southeast had encountered water-bearing Oriskany sandstone.

TABLE II

RECORD OF WELLS DRILLED IN TYRONE FIELD

Well No.	*Operating Company*	*Depth to Top of Sand (in Feet)*	*Initial Open Flow (in Cubic Feet)*
1	B. Q. D. C.*	2,075	5,750,000
2	B. Q. D. C.	2,004	10,880,000
3	B. Q. D. C.	2,002	6,079,000
4	B. Q. D. C.	2,044	7,863,000
5	B. Q. D. C.	2,125	2,700,000
6	B. Q. D. C.	2,044	6,225,000
7	B. Q. D. C.	1,957	2,900,000
8	B. Q. D. C.	2,085	3,500,000
9	B. Q. D. C.	2,150	4,600,000
10	B. Q. D. C.	2,186	4,500,000
11	B. Q. D. C.	2,114	150,000
12	B. Q. D. C.	2,102	4,500,000
13	B. Q. D. C.	2,115	3,800,000
14	B. Q. D. C.	2,038	9,500,000
A	Carpenter	2,091	Salt water
B	Carpenter	2,057	340,000†
C	Stone	2,002	Dry
D	Carpenter	2,035	Salt water
E	Erwin	1,887	737,000
F	Erwin	1,913	3,376,000
G	Carpenter	2,060	Salt water

*Belmont Quadrangle Drilling Corporation.

†Makes some water.

FARMINGTON FIELD

The Farmington field was discovered in September, 1930. Its location on the Sabinsville anticline, in Tioga County, Pennsylvania, is shown in Figure 5. In this illustration the structure of three quadrangles is given. The solid contours are taken from the Elkland-Tioga Folio of the United States Geological Survey, and the dashed contours have been calculated by the writer from strikes and dips taken on surface beds. The discovery well is reported to have had an initial open flow of 12,000,000 cubic feet, and after blowing wild for more than 2 weeks it had a closed-rock pressure of 1,650 pounds per square inch.

Since the drilling of the discovery well, three other producing wells and several dry holes have been completed. The field is by no means defined at the present time. The location of some of the wells is shown in Figure 5, and a record of these wells is given in Table III.

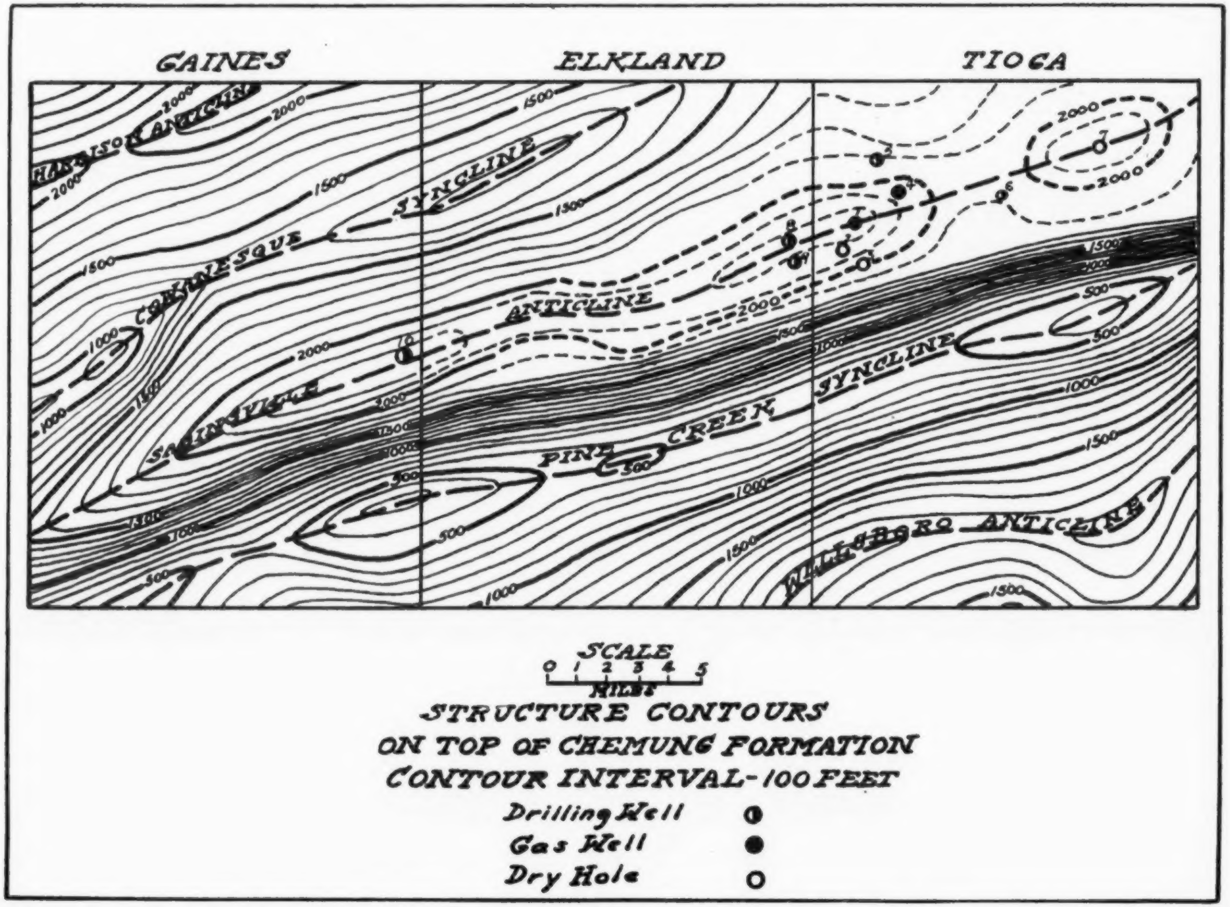

FIG. 5.—Structure map of Gaines, Elkland, and Tioga quadrangles, in Potter and Tioga counties, Pennsylvania, showing elevation of top of Chemung formation above sea-level.

TABLE III

RECORD OF SOME WELLS IN FARMINGTON FIELD

Well No.	*Operating Company*	*Depth to Top of Sand (in Feet)*	*Initial Open Flow (in Cubic Feet)*
1	North Penn Gas Company	4,005	12,000,000
2	North Penn Gas Company	4,350	Salt water
3	Peoples Natural Gas Company	4,372	Salt water
4	Benedum and Trees	3,773	9,000,000
5	J. E. Traynor		Drilling
6	Penn-United	4,197	66,000,000
7	Peoples Natural Gas Company		Salt water
8	Penn-Ohio Gas Company		Drilling
9	Penn-Ohio Gas Company		20,000,000
10	Peoples Natural Gas Company		Drilling

The driller's record of the discovery well is given in Table IV. No attempt has been made to correlate the various formations because of the lack of more reliable data.

TABLE IV

DRILLER'S LOG OF DISCOVERY WELL OF FARMINGTON FIELD, COMMONWEALTH OF PENNSYLVANIA, COUNTY OF TIOGA, TOWNSHIP OF FARMINGTON. NORTH PENN GAS COMPANY'S PALMER NO. 1. COMPLETED, SEPTEMBER 10, 1930. OPEN FLOW, 12,000,000 CUBIC FEET OF GAS.

	Depth in Feet
Slate, light gray	260
Sand, light gray	267
Slate, light gray	275
Sand, gray	280
Slate, dark gray	380
Sand, gray	390
Shale, dark gray	457
Sand, dark gray	465
Sand and shells, light gray	695
Slate, gray	865
Shale, dark gray, little gas	950
Shells, gray	967
Sand, gray	975
Shale, dark gray	1,005
Sand, dark gray	1,012
Slate and shells, dark gray	1,050
Slate, light gray	1,065
Slate and sand, light gray	1,078
Slate, dark gray	1,145
Sand, dark gray, little gas	1,160
Slate, light gray	1,285
Shale, black	1,297
Slate, dark gray	1,370
Sand, light gray	1,384
Slate, shale, shells, black	1,560

TABLE IV—*Continued*

	Depth in Feet
Sand, gray	1,592
Broken sand, gray	1,615
Sand, gray	1,622
Broken sand, dark gray	1,690
Shale, dark gray	1,696
Shells, gray	1,705
Slate, gray	1,716
Broken sand, gray	1,735
Sand, gray	1,741
Broken sand, gray	1,756
Slate and shells, gray	1,830
Shale, dark gray	1,842
Slate and shells, gray	1,995
Slate, gray	2,030
Shale, light gray	2,05c
Sand, gray	2,070
Slate and shells, gray	2,090
Sand, gray	2,097
Slate and shells	2,125
Slate, black	2,270
Sand, gray	2,296
Shell, gray	2,312
Slate, gray	2,330
Broken sand, gray	2,360
Sand, gray	2,371
Shale, gray	2,392
Sand, dark gray	2,405
Shale, gray	2,434
Sand, gray	2,445
Slate and shells, light gray	2,470
Sand, gray	2,595
Lime, gray	2,605
Shale, dark gray, with pyrite	2,654
Slate and shells, gray	2,667
•Slate, dark gray	2,690
Shale, dark gray	2,765
Slate and shells, dark gray	2,777
Shale, gray and black	3,015
Lime, sandy, gray	3,100
Shell and lime, dark gray	3,120
Shale, dark gray	3,180
Shale, gray	3,500
Lime, gray	3,557
Shale, dark gray with pyrite	3,930
Pyrite, black	3,940
Pyrite, limy, black	3,950
Shale, calcareous	3,970
Shale, black	3,980
Lime, slaty, black	3,987
Lime, sandy, black	3,995
Lime, dark gray	4,005
Sand, gray, hard, Oriskany	4,012

CONCLUSIONS

Natural gas is not produced in sufficient quantities in New York to supply the present demand; hence, much gas is annually imported from

Pennsylvania. This condition has stimulated geological investigations and exploratory drilling which has resulted in the discovery of two new fields during the past year. The two important factors which must be considered in the location of test wells are that (1) gas production from the Oriskany conforms rather closely to closures on anticlinal axes, and (2) the irregularities in Oriskany deposition so govern the accumulation of gas that studies of the deposition and lateral extent of the sandstone are of equal importance to actual structural mapping.

TRUNCATION OF MARICOPA SANDSTONE MEMBERS, MARICOPA FLAT, KERN COUNTY, CALIFORNIA[1]

E. R. ATWILL[2]
Los Angeles, California

ABSTRACT

In the Maricopa Flat, Kern County, there is a small area which has recently been intensively drilled, and in which some anomalous conditions were encountered. The writer, by means of many well sections and structure contour maps, has attempted to explain in part the reasons for the existence of these conditions.

The purpose of the writer is to present the subsurface geology of a restricted area in the Maricopa Flat, namely, that one which is locally designated the Signal Oil and Gas Company area, and which occupies all of Section 8 and adjoining parts of Sections 7, 9, 16, 17, and 18, T. 11 N., R. 23 W.

It was formerly believed that there was no regularity of beds here in the older formation that was penetrated (variously called the Maricopa formation, or the "Brown shale"), and that oil was produced from certain sand pockets. It was considered exceptionally good luck to obtain a producing well (incidentally it should still be so considered, but for different reasons)—the operator having been fortunate enough to connect with one of the separate pockets. The name "Signal" zone was given to this supposed group of saturated sand pockets occurring at depths ranging from 400 to 600 feet below the Etchegoin-Maricopa contact. Later, certain wells disclosed saturated sands at, and immediately below, this contact; and the idea of a "contact" zone was accepted. But it was not quite understood why this so-called zone was found in some wells at the contact in the Maricopa, and in some off-sets only shale was found at that horizon.

In an effort to solve this problem, a series of detailed well sections and structure contour maps was planned. Thanks are expressed in this paper to the operators in the area who very kindly granted permission for the use of their well data as therein set forth. The cores of the critical

[1]Read before the Pacific Section of the Association at the Los Angeles meeting, November 6, 1930. Manuscript received, February 7, 1931.

[2]Geologist, Union Oil Company of California.

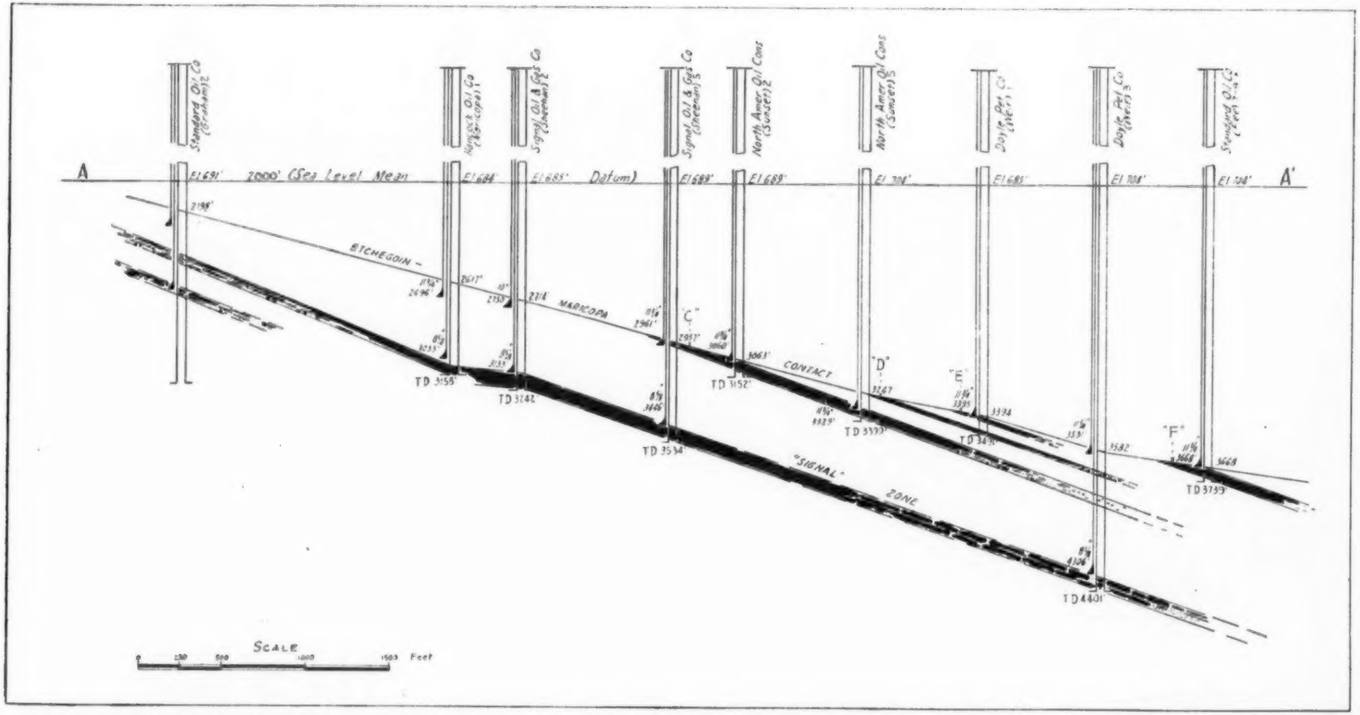

FIG. 1.—Longitudinal section which approaches close to axis of Maricopa fold (Fig. 5) at wells Hancock Company's Maricopa No. 1, Signal Oil and Gas Company's Sheehan No. 2 and Sheehan No. 5. At this point oil is held in the "Signal" zone in commercial quantities. Angular unconformity between Etchegoin and Maricopa permits truncation of higher Maricopa sand members against contact, and in these sand members commercial production is secured for a short distance down dip.

wells were examined in the field; but for the other wells, where possible, the detailed core record of the operator was used. Only the lithology, megascopic fossils, and angles of dip were included in the field description, no thorough microscopic study being attempted. Whenever a well was surveyed, corrections in dip were made for any deviation reported.

With these data available, the sections were drawn, and it was seen that an angular unconformity ranging from 5° to 10° exists between the Etchegoin and Maricopa formations, and that sand members of the Maricopa are truncated against the more gently dipping Etchegoin. The base of the Etchegoin formation is composed of hard, fairly well cemented, coarse conglomeratic sand which forms the seal for the Maricopa sands.

It may be mentioned that a possible lack of uniform cementation in this basal member might explain in part the varying degrees of Baumé gravity (19°-25°) of the oil obtained from the different truncated sands. Where the cementation was slight, part of the higher constituents would escape up into the Etchegoin; and where well cemented, they would be held in the truncated member. However, no detailed study was made of this particular phase, and the suggestion is a mere speculation.

From the sections it was also seen that the lower zone ("Signal" zone) was more or less regular, and seemed to be slightly arched in some of the transverse sections. Therefore, an attempt was made to contour this zone. The result gave evidence of a small eastward-plunging anticlinal nose, which is pre-Etchegoin in age, inasmuch as no reflection of it is seen in the Etchegoin as shown by a structure contour map of the Etchegoin-Maricopa contact. Further evidence to strengthen the possibility of this nose is found in the areal geology of the low foothills, 3 miles farther west. Here the Maricopa exposures indicate a reversal, suggesting also an eastward-plunging anticlinal nose; immediately south of this there is positive evidence of an eastward-plunging syncline.

It is believed that this slight arching in the Maricopa provides the means for accumulation in the "Signal" zone. Also it localizes in commercial quantities the oil in the truncated sandstone members along its flanks and down the axis.

These truncated sands seem to lens out along the strike, north of the axis of the anticlinal nose. It is difficult to predict at what point this lensing-out of each sand occurs, inasmuch as the lensing seems to be irregular. Nor is it any easier to determine where a new sand member is truncated. However, there is sufficient information available concerning the known sand members to guide future restricted drilling in this area.

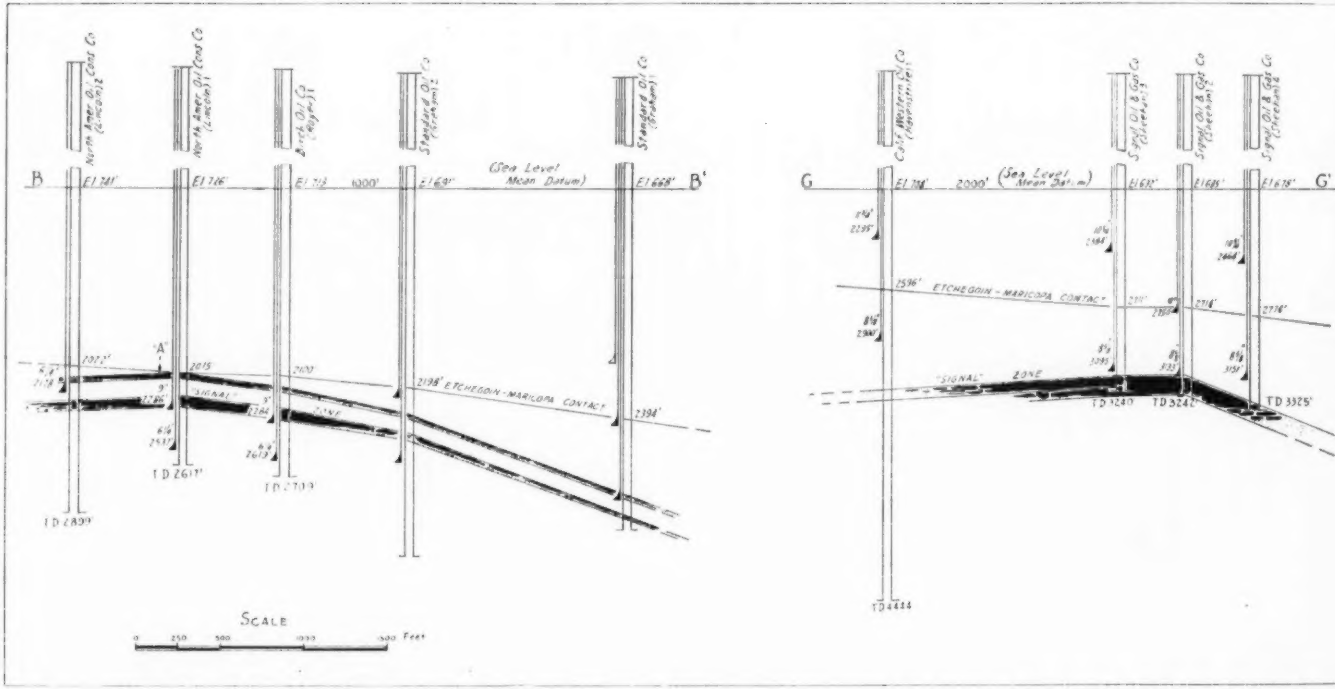

FIG. 2.—Transverse sections indicating the pre-Etchegoin arching of the Maricopa formation, which is believed to be the controlling factor for accumulation in the "Signal" zone. Notice in section *B-B′* the dying-out of the sand members on the right, or north, flank of the fold.

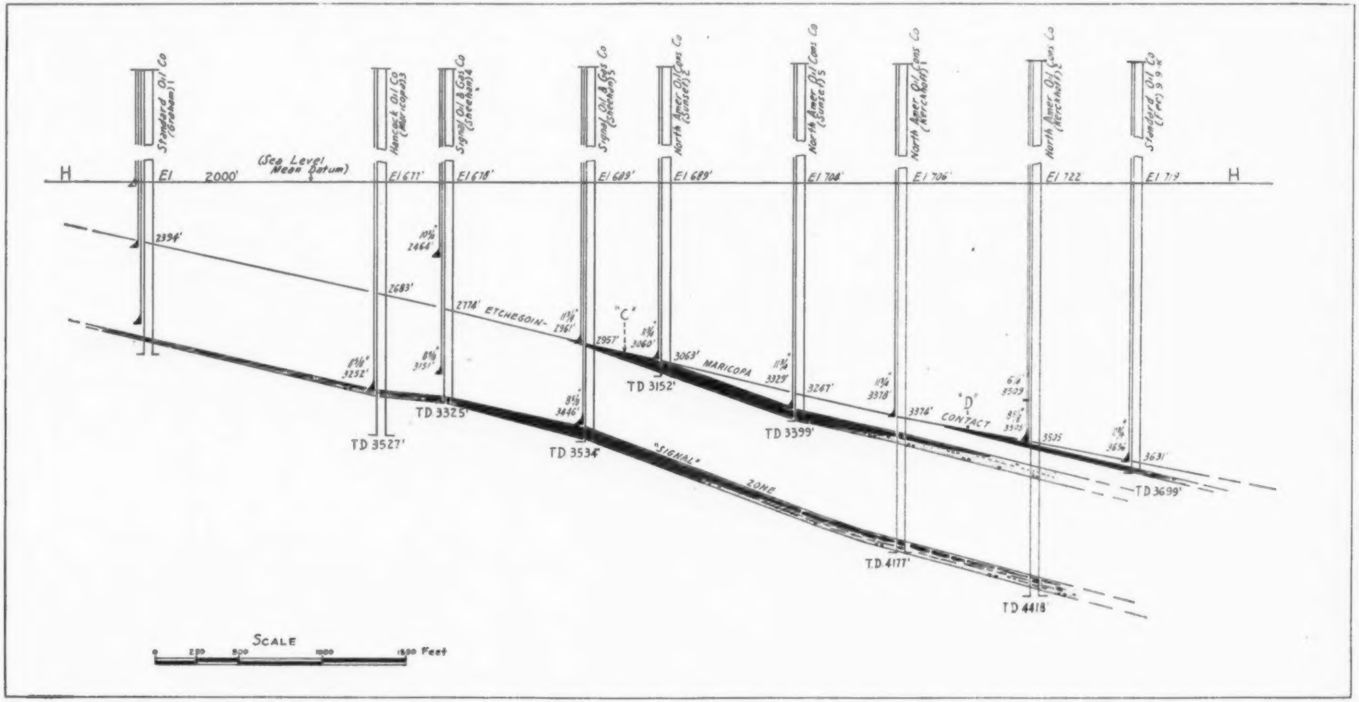

FIG. 3.—Longitudinal section also showing localization of oil in the "Signal" zone where the section passes close to the curving axis of the Maricopa fold (Fig. 5) at Signal Oil and Gas Company's Sheehan No. 4 and Sheehan No. 5. Standard Oil Company's Graham No. 1 lies considerably farther north of the axis than these wells, at a point where the zone has commenced to lens out. Sand "C" is an excellent and typical example of the manner of accumulation in the truncated sand members.

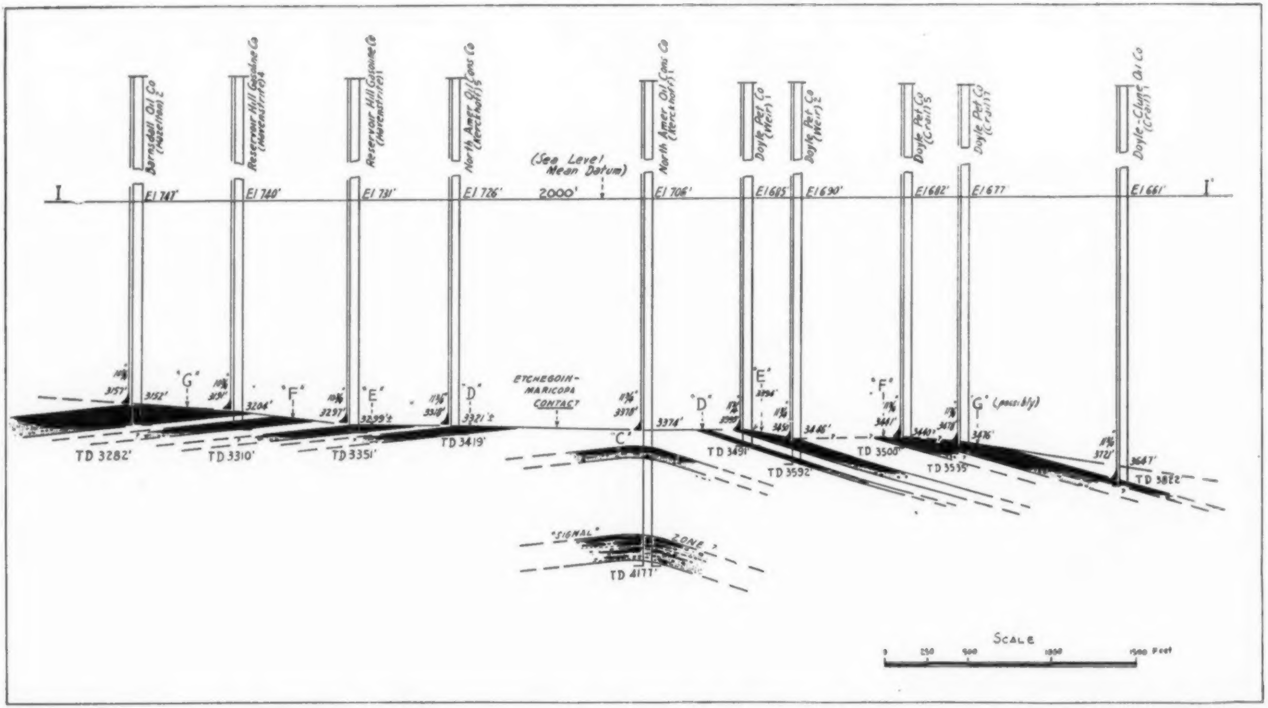

FIG. 4.—Transverse section indicating postulated asymmetry of pre-Etchegoin fold. Truncated sand horizons on left flank might be considered as a single sand unit, or the coalescing of the sand fingers dying out into the shale on the right flank.

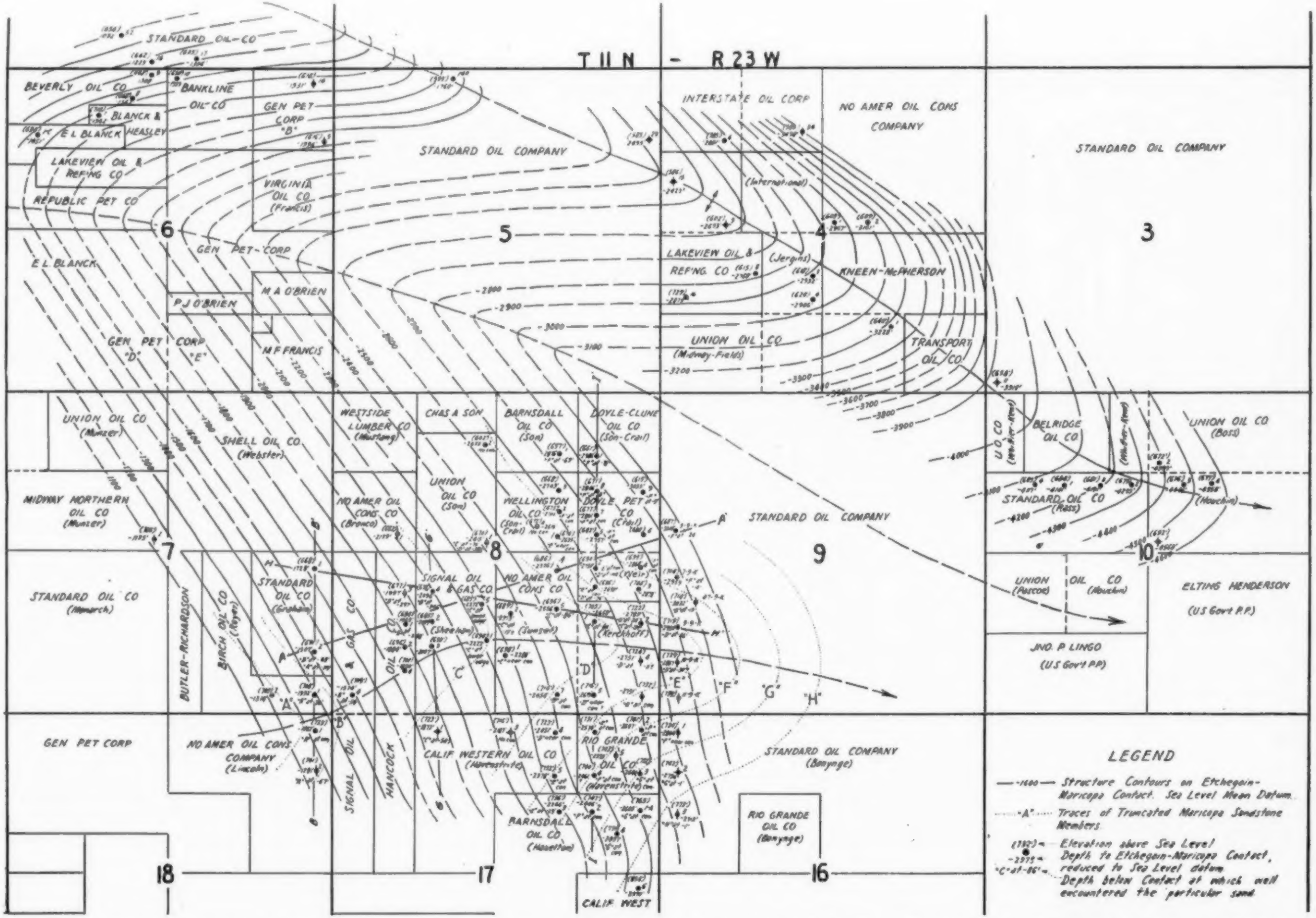

FIG. 5.—Subsurface structure of Maricopa Flat. West (left)-east (right) length of area mapped, 4 miles. Contours, elevations, and depths shown in feet.

The sands seem to be thicker on the south flank of the nose, and it is quite possible that here the various tongues of sand, extending northward, unite and form a fairly thick body of sandstone. This would explain the difficulty experienced in satisfactorily separating the individual members. At this locality, also, the largest producers are obtained. Flowing wells are brought in with initial production ranging from 3,000 to 4,000 barrels per day, as compared with wells on the north flank having initial production ranging from 1,000 to 2,000 barrels. It should be mentioned, also, that the well sections suggest an asymmetry of the anticlinal nose, the north flank being the steeper (having approximately a 20° dip). The south flank is not well defined, because of insufficient well data, but it seems to be considerably more gentle.

In wells drilled too close to the lower point of truncation of a sand, or up the dip from this point, attempts to obtain production from this particular sand are ordinarily unsuccessful, but oil may be obtained from a lower sand that is truncated farther up the dip.

In order to outline this feature, a map was constructed which, though not a structure-contour map in the accepted sense, shows to some degree the probable productive limits of these sand members. Each sand was projected up the dip to the Etchegoin-Maricopa contact, and the points of truncation of the lower planes of the sands were used to establish the traces of these planes.

GEOLOGICAL NOTES

CRETACEOUS-EOCENE CONTACT NORTH OF COALINGA, CALIFORNIA

The exact upper limit of the Cretaceous and the lower limit of the Eocene strata and their probable relation to each other in the Coalinga district, were first clearly set forth by Anderson and Pack.[1] The Moreno, or Upper Cretaceous, was here thoroughly described and its probable unconformable relation with the Eocene, above, postulated. Their reasons for believing that an unconformity existed between the Moreno and the Eocene were based on paleontological evidence found in several localities and good structural evidence in at least one locality. Regarding the latter, they state:

> This is on the north bank of Silver Creek about a third of a mile south of its junction with Panoche Creek, where a recent cutting on the County road, at its turn around the point of the hills, exposes the contact between the Moreno and Martinez (?) formations. Here the great body of dark clay of the Martinez (?) has a basal fossiliferous sandstone and conglomerate that lies with jagged contact upon the Moreno shale, affording fairly clear evidence of unconformity.

More recent improvements along this same road have further exposed this contact. It was seen by the writer on two occasions. When first visited in company with G. D. Hanna early in 1930, good Martinez Eocene fossils were collected from the loose sandy bed at the base. *Foraminifera* are also present here in the fossiliferous sand and in some of the shale beds a few feet above it. That an unconformity is present here, between the Moreno and the Martinez, can not be doubted.

In March, 1931, while working in the Coalinga district, the writer examined the supposed "shale on shale" contact of the Cretaceous and Eocene in the upper end of Oil Canyon, northeast of old "Oil City." Here the Moreno is typically purplish brown and weathers at the surface into fine loose chips. The Eocene above is gray clay shale, and, at a distance, the break with the darker Moreno below is indicated by a well marked color change. Due to the light rainfall in the region and the shaly nature of the adjacent formations, a mantle of loose soil 3

[1] *U. S. Geol. Survey Bull. 603* (1915).

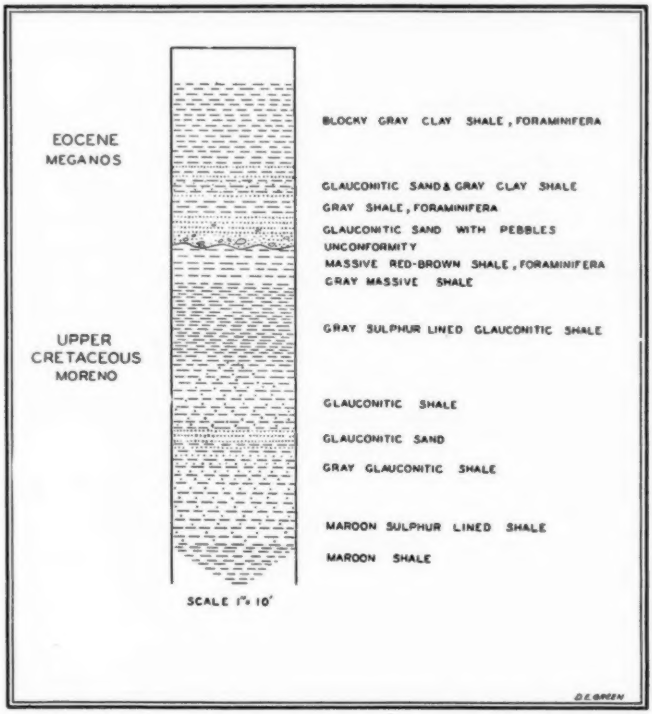

FIG. 1.—Trench section of Cretaceous-Eocene contact in NE. Cor., SE. ¼, Sec. 17, T. 19 S., R. 15 E., M. D. M., Fresno County, California.

feet thick obscures the natural bedding and conceals the formational contacts. In order to see the contact, it is necessary to dig deep. Commencing in the deep stream-cut east branch of the canyon, the writer uncovered the contact by the removal of a few feet of slumped shale. At the base of the Eocene, he found a bed of glauconitic sand and shale pebbles 3 feet thick with granite pebbles and cobbles at the contact. The cobbles are well rounded and rather sparingly scattered through a shaly, sandy matrix. The Moreno below is massive, hard, red-brown shale well planed off at the top. It contains arenaceous *Foraminifera* in profusion, most of which have siliceous cementing material. Calcareous *Foraminifera* are rare. The irregular but smooth surface of the reddish

Moreno is readily traced below the greenish gray detrital mass lying on it.

About ¼ mile north of the first locality and on a steep hillside, unchanged by slumping, the writer dug a deep trench across, and at right angles to, the supposed line of contact of the two formations. The lower end of the trench was begun well below the contact in purplish, chocolate brown Moreno shale and ended in the gray clay shale of the Eocene.

The Moreno, as in the first locality, is overlain by a bed of glauconitic sand, but more purely glauconitic and less shaly; also, only a few granite pebbles were seen. Above the basal glauconite, a few thin beds of shale and glauconitic sand are interspersed, above which massive, blocky gray shale persists.

The Moreno at the contact is reddish brown, massive, and tough with the ordinary arenaceous *Foraminifera*, but below the top 2 feet, becomes gray with sulphur-lined joints and in places is highly glauconitic. Below the grayish glauconitic part, the shale is the typical purplish brown or maroon clay characteristic of the greater part of the Moreno.

The gray shale above the contact contains plentiful Eocene *Foraminifera* which have been found in the same stratigraphic position in Ragged Valley, Domengine Creek. In the Domengine Ranch locality, the basal glauconitic part forms hard sandstone which protrudes above the softer clay shale.

The age of this basal Eocene formation in this locality is somewhat in question; the earlier writers called it Martinez (?), but it was renamed Meganos by Clark,[1] and later workers in the area have followed this classification.

The contact which has for so long been considered as simply "shale on shale" is therefore seen to be in reality an unconformity of considerable importance. The amount of angular discordance (if present) was not great enough to be noticeable in the trench. Figure 1 is a drawing of the trench section in detail.

C. C. Church,
Paleontologist

Associated Oil Company
San Francisco, California
April 20, 1931

[1]B. L. Clark and A. O. Woodford, "The Geology and Paleontology of the Type Section of the Meganos Formation (Lower Eocene of California)," *Univ. California Pub., Bull. Dept. Geol.*, Vol. 17, No. 2 (1927), pp. 63-142, Pls. 14-22.

REPORT OF ASSOCIATION COMMITTEE ON STRATIGRAPHIC NOMENCLATURE

Preliminary report.—The following principles are presented as a tentative guide to be followed in the selection of names for new stratigraphic units. These rules should apply to a unit which crops out as well as to one which is found only through underground exploration.

1. There are two kinds of nomenclature, technical and non-technical or common. The object of technical nomenclature is precision of definition and understanding. The object of common or non-technical geologic nomenclature is convenience. Examples are the following.

Common or Non-Technical Name	*Technical Name*
Indiana limestone	Salem limestone
Salt sand	Bartlesville sand of Oklahoma Conoquenessing sand of Pennsylvania-West Virginia Other sands
Ottawa sand Crystal City, and other trade names	St. Peter sandstone
Blue limestone	Leadville limestone

As far as possible, geologists should use technical nomenclature.

2. Inquiry should *always* be sent to Miss M. Grace Wilmarth, U. S. Geological Survey, Washington, D. C., as to the availability of the proposed name. Miss Wilmarth has a complete index to the stratigraphic literature of the United States as far as names and classifications are concerned and is prepared to give prompt answers to such questions as whether a particular geographic name has had previous use as a stratigraphic name; what are the original and current definitions of a particular formation; what is the currently accepted age or classification of any particular unit; where are references to descriptions of stratigraphic sections of restricted areas, and other similar general or specific questions. In proposing a new name, mention should be made of the inquiry sent to Miss Wilmarth, by a footnote, as "Name available according to records of the Committee on Geologic Names, U. S. Geological Survey."

3. The principle of the nomenclature of strictly subsurface units (stratigraphic units which are not known to crop out) should be the same as for surface units or units which do crop out. A formation which crops out and has received a name should be designated by the same name if it is encountered below the surface in drilling, that is, Wapanucka limestone, Dakota sandstone, et cetera.

4. It is generally desirable to name a new stratigraphic unit, either surface or subsurface, from the geographic locality near which or under which it is well developed, such as Fayetteville shale, Monterey shale, and Bartlesville sand.

5. In proposing a new name for a subsurface unit, it is desirable to describe the type section as to the following features.

(1) Location of type locality as to section, township, range, survey, farm, block, et cetera, farm name and name of operating company; date of drilling; elevation of surface at well head and total depth of hole

(2) Description of the new formation as to lithology, drilling characteristics (hard, soft, sticky, caving, water-bearing, oil-bearing, et cetera), and definition of the upper and lower boundaries

(3) Fauna and flora of the new geologic unit

(4) Nature of overlying and underlying formation or unit and character of the contacts

(5) Correlation and position in the geologic time scale

6. Cuttings or samples, properly labelled, should be sent to the state geologist or the state geological survey of the state in which the type locality is found, for permanent record. The location of other sets of samples from the type locality, together with the disposition of the type set, should be mentioned in the description of the new subsurface unit.

Toronto recommendation.—The National Committee on Stratigraphic Nomenclature met at the University of Toronto, Toronto, Canada, on January 1, 1931. The National Committee consists of representatives from the United States Geological Survey, the Geological Society of America, the Association of State Geologists, the Canadian Geological Survey, and The American Association of Petroleum Geologists. The Association committee, together with J. J. Galloway, submitted the following two paragraphs for inclusion in the final rules of stratigraphic nomenclature which is the objective of the national committee.

The nomenclature of subsurface stratigraphic units (those units which are not known to be exposed at the surface) are subject to the same principles and should follow the same rules as those for surface stratigraphic units. Particularly a subsurface unit should be named from a geographic locality under which or near which it was first discovered or is best developed and which becomes the type locality. Geologists should avoid using names for subsurface units which have already been used for surface units.

RECOMMENDATION. It is recommended that a set of the original cuttings or samples which were responsible for the naming of a new unit be deposited with the state geological survey of the state in which the type locality occurs.

Announcement.—At a meeting of the Association representatives on the National Stratigraphic Nomenclature Committee together with other interested geologists, which was held in San Antonio, March 20, 1931, it was decided that one of the best methods of aiding the National Stratigraphic Nomenclature Committee in preparing a set of rules of nomenclature would be for the members of this Association to submit the problems of nomenclature with which they have to deal in their work, to the end that as many types of problems as possible be available for study by the general committee at the Geological Society of America meeting to be held in Tulsa in December, 1931. Most problems of stratigraphic nomenclature may be solved by general rules, whereas others can be solved only by special study and a local rule. It is hoped that we may have available a large number of types of problems so that the rules, when drafted, will be as comprehensive as possible and cover most problems of stratigraphic nomenclature arising in petroleum geology.

We should therefore greatly appreciate receiving specific problems in nomenclature submitted in the following manner.

(1) Brief statement of facts
(2) Brief statement of the problem
(3) Rough sketch or diagram illustrating the facts and the problem

ASSOCIATION REPRESENTATIVES ON NATIONAL
STRATIGRAPHIC NOMENCLATURE COMMITTEE,
A. I. LEVORSEN, *chairman*

1740 SOUTH ST. LOUIS AVENUE
TULSA, OKLAHOMA

DISCUSSION

BACTERIAL GENESIS OF HYDROCARBONS FROM FATTY ACIDS[1]

The work of Taylor[2] in England during the last few years has an important bearing on the retention of the gaseous or oily products of the decomposition of organic matter accumulated in sediments. It seems from this work that the only type of clay which is truly impervious at or very soon after its deposition is a hydrated sodium clay. Other clays are flocculent; therefore, pervious. This work also shows that any original clay deposited in water will be changed to a sodium clay on contact with salt water. By the phenomenon of base exchange, developed by research in soil chemistry, sodium replaces other bases in clays when in contact with salt water. However, this sodium clay is flocculent. If the sodium clay is wetted by fresh water, it becomes hydrated and is no longer flocculent, but impervious. Taylor has analyzed many roof clays of oil sands from many oil fields and has uniformly found sodium clays over oil sands. He plans to extend his work to more samples. At present it seems conclusive that sodium clays are commonly the roof clays (impervious blanket) of oil sands.

Under what precise geological conditions base exchange occurs uniformly through the mass of a clay stratum by the action of first salt water and then fresh water remains to be determined by observation. Strand-line deposition, oscillating sea-level, coastal bays with periodic incursions of fresh waters, and unconformities are situations which come to mind, some of which are noted by Taylor. The variable occurrence of such favorable conditions along a shore line where source beds of petroleum are being deposited suggests one reason why some structures in a petrolific province may be productive and others unproductive.

Paul Weaver has suggested that the composition of clays, revealed by this work, indicates that chemical analysis of clays may yield data for correlation of well logs and sections in clay series lacking other adequate criteria.

W. Armstrong Price

Corpus Christi, Texas
April 9, 1931

[1]Discussion of Lewis A. Thayer's paper, "Bacterial Genesis of Hydrocarbons from Fatty Acids," presented before the Association at the San Antonio meeting, March 20, 1931. The paper was published in this *Bulletin*, April, 1931.

[2]E. McKenzie Taylor, "The Bearing of Base Exchange on the Genesis of Petroleum," *Jour. Inst. Petrol. Tech.*, Vol. 14, No. 71 (December, 1928), pp. 825-40; "The Replaceable Bases in the Shales and Clays Overlying Petroliferous Strata," *Jour. Inst. Petrol. Tech.*, Vol. 15, No. 73 (April, 1929), pp. 207-10; "A Comparison of the Conditions of Occurrence of Bituminous Coal and Petroleum," *Jour. Inst. Petrol. Tech.*, Vol. 15, No. 74 (June, 1929), pp. 372-84.

PENNSYLVANIAN OVERLAP IN UNITED STATES

A. I. Levorsen's article in the February number of this *Bulletin*, pp. 113-48, "Pennsylvanian Overlap in United States," contains data of the greatest interest and importance to one concerned with the broader phases of Pennsylvanian geology. His maps and diagrams, which are valuable and concise summaries of information derived from scattered literature, are the results of painstaking labor. It is to be hoped that his example may inspire others to collect and review the recorded facts relating to geological problems of similar character.

Levorsen states that in coördinating his data he has been forced to decide one way or another regarding many controversial matters; this necessity is readily appreciated. Some of his decisions, however, are not entirely in accordance with prevailing modern acceptance. One matter which is of particular importance in the upper Mississippi and lower Ohio valleys is the classification of the Ste. Genevieve limestone which Levorsen includes with the Chester in the Upper Mississippian. All stratigraphers and paleontologists who have done any considerable amount of work on the Mississippian formations of this area during the last 25 years, with the exception of Charles Butts, have agreed that the Ste. Genevieve limestone, both stratigraphically and faunally, is much more closely related to the St. Louis than to the Chester and consequently is to be included within the Lower Mississippian. (Incidentally, the Chester plus the Ste. Genevieve in southern Illinois achieves a maximum thickness of more than 1,500 feet.)

It is unfortunate that Levorsen has chosen the top of the Pottsville for his principal plane of reference, as even the approximate position of this horizon is unknown outside of the northern Appalachian region. The top of the Allegheny, however, which can be determined faunally with much greater precision, corresponds approximately with the top of the Carbondale in Illinois and the top of the Des Moines in the northern Mid-Continent region. By raising this reference plane only approximately 200 feet in the northern Appalachian region to the top of the Allegheny much greater accuracy might have been achieved.

Undoubtedly Levorsen has accepted the equivalence of the top of the so-called Pottsville of Illinois with that of the original formation farther east, although it is now known that this correlation, based on preliminary paleobotanical studies made almost 25 years ago, is quite inadequate for modern stratigraphic requirements. However, Levorsen is not to be criticised for this acceptance, because the results of recent investigations along these lines have not yet been published. It should be noted here that subsequent remarks concerning the Pottsville of the Eastern and Western Interior basins refer to the so-called Pottsville of Illinois and not to the Pottsville of the northern Appalachian district; thus, they conform with Levorsen's usage of the term in these areas.

Many divergent correlations of the formations in the different districts of the Western Interior basin have appeared from time to time, most of them unaccompanied by any discussion of the data on which they are based, and Levorsen undoubtedly has authority for the correlations presented in his

tenth figure. He deserves no criticism for following these correlations, but, as they are the basis for certain of his conclusions regarding overlaps, they can not be allowed to pass unnoticed. The lower Pennsylvanian formations in the columns devoted to Arkansas, Kansas, and Oklahoma are uniformly placed too high. The Morrow, which is considered to be upper Pottsville, contains a fauna much older than the oldest Pennsylvanian faunas of Ohio where the section as shown in Figure 2 is represented as starting at the base of the middle Pottsville. The Wapanucka, which is placed somewhat lower than the Morrow, is probably almost its exact equivalent. The Cherokee shale of Kansas, which is considered Allegheny, is, excepting approximately the upper 100 feet, equivalent to the Pottsville of Illinois. Finally, in southern Oklahoma all of the beds below the Wetumka, as developed in the vicinity of Ada, are Pottsville. The paleontological data on which these correlations are based can not be presented at this time because most of the forms relied on are either undescribed or else belong to groups, the classification of which is in a chaotic condition. This matter will form the subject for a paper which the writer intends to prepare soon.

On page 118 Levorsen states that Middle Pennsylvanian beds (Upper Allegheny) overlap the Lower Pennsylvanian (Pottsville) and form the basal Pennsylvanian deposits of northwestern Illinois and Iowa. He has no means of knowing that the idea of such an overlap is erroneous and that it resulted from two miscorrelations in the Rock Island region. The field evidence regarding this is now being prepared for publication.

There seems to be little doubt that overlap of Lower Pennsylvanian beds did occur adjacent to the basins of very thick Pottsville sedimentation such as those occurring in southwestern West Virginia and southeastern Oklahoma and Arkansas. However, no convincing evidence is known suggesting any extensive progressive overlap about the northwestern border of the Appalachian basin, about the margins of the Eastern Interior basin, or about the northern part of the Western Interior basin where Pennsylvanian beds occur in outcrop. There is a marked thinning of the Lower Pennsylvanian section on the northern and eastern flanks of the Ozark region, and at approximately the place where Levorsen's 500-foot contour on Figure 17 crosses into Missouri, the Pottsville is reduced to a thickness of not more than 20 feet. This thinning, however, is not caused primarily by overlap, but rather by thinning and wedging out of various clastic units at many horizons in the section involved. From this region northward the Pottsville becomes progressively thicker and exceeds 200 feet in the vicinity of Rock Island. On the west its thickness increases still more, and in south-central Iowa as much as 400 feet of strata are referable to the Pottsville.

The statement has recently been made by several different writers, and is reiterated by Levorsen on page 128, that there is progressive northward overlap of several Lower Pennsylvanian units in the Mid-Continent region, but the writer of this discussion has not seen any evidence for this conclusion. In view of the lack of evidence of such overlaps about the borders of the various basins where Pennsylvanian beds are exposed to direct observation, this matter seems to be of considerable importance, and a paper on this subject

by some geologist to whom pertinent data are available would be a distinct contribution to Pennsylvanian stratigraphy.

Most of the preceding remarks have been concerned with errors resulting from Levorsen's unfamiliarity with Pennsylvanian stratigraphy in the eastern United States, and although these errors might prove very misleading to others equally unacquainted with the facts, they may be passed over with leniency. There remains, however, a matter which can not be so easily overlooked. In consulting his "more than one thousand" references Levorsen must have read something concerning the nature of the Pennsylvanian sediments in the different regions of their occurrence, but such information did not find a place in the maps and diagrams which he prepared. This has not lessened the value of his maps and diagrams, but they are certainly an inadequate source of information on which to base conclusions regarding the source of Pennsylvanian sediments.

All stratigraphic evidence is opposed to Levorsen's conclusion that the so-called continental backbone was the predominant source of the Pennsylvanian sediments. It is well known that the clastics of the Appalachian basin become progressively thicker and coarser toward the southeast, and a similar situation prevails in the Eastern Interior basin. In southern Oklahoma the Pennsylvanian section is very thick, is dominated by clastic beds, and contains few and thin limestones. In the northern part of the state, the section has changed so greatly that no detailed correlation of the two sections has yet been achieved. Only the more persistent sandstones extend northward into Kansas, and in Nebraska the Pennsylvanian section is almost totally lacking in coarse clastic material. The distribution of Pennsylvanian sandstones and conglomerates provides incontrovertible evidence that these sediments were derived chiefly from a land mass at the south and southeast.

The Paleozoic land mass of Appalachia is the most certainly known topographic feature of North America during ancient geologic time. From the Silurian to the Permian it was an almost constant contributor of sediments to the interior seas, and it served as a barrier cutting out the migrations of European faunas into the interior of North America. Surely Levorsen depreciates the importance of Appalachia and Llanoria when he refers to them as "relatively local disturbances" which he evidently even subordinates to the Wichita-Arbuckle Mountains and the Cincinnati-Nashville arch (p. 148)! The presence of a highland area on the southeastern and southern flank of the basins of thickest Pennsylvanian sedimentation makes impossible the northwestward advance of a Pennsylvanian sea as postulated by Levorsen (p. 137).

By comparing his thickness contours for the Pottsville with depth contours of the Gulf of Mexico (p. 139), does Levorsen intend to imply that during Pennsylvanian time the edge of the continental shelf existed approximately 500 miles or more north of its present position, and that the thick Pottsville sediments accumulated in relatively deep water? Aside from the somewhat analogous spacing of two sets of contours of widely differing nature, there is no evidence in favor of this conclusion. Neither can the thickness contours be considered as representing, inversely, the former topographic configuration of the eastern United States, even in a general way. There is too much evidence of down-warping in the basins of deposition at intervals throughout Pennsylvanian time.

If the Pennsylvanian sediments were derived principally from the "continental backbone" and deposited in a sea advancing toward the northwest, as Levorsen believes, shoreward deposits should be most dominant on the northwest near the old land mass, and open sea deposits should predominate on the southeast away from it. This condition is exactly the reverse of that which actually occurs. Conglomerates, sandstones, and coal beds (formed from terrestrial vegetation) are much more conspicuous members of the Pennsylvanian section in the Appalachian and Eastern Interior basins and in southern Oklahoma and Arkansas than are limestones and calcareous fossiliferous marine shales, and in Missouri, Kansas, Iowa, and Nebraska typical marine limestones and shales dominate the Pennsylvanian section down to and including the upper part of the Pottsville. Furthermore, in Pennsylvania, West Virginia, and Ohio the Upper Pennsylvanian is entirely non-marine, while marine limestones and fossiliferous shales are the most conspicuous members of contemporaneous sediments in the northern Mid-Continent region.

The stratigraphic evidence, which has been entirely ignored by Levorsen, indicates most positively that the Pennsylvanian seas, at least after early Pennsylvanian time, advanced into the eastern United States from the west and that the sediments deposited in them and on their borders were derived principally from Appalachia and Llanoria. These seas may have been bounded on the northwest by the pre-Cambrian "backbone," but even this is doubtful and may be known only as the result of subsurface studies.

Like many other writers, Levorsen refers to a Pottsville sea (p. 137). Such an expression is misleading, as neither were all Pottsville strata deposited under marine conditions, nor were all of the marine beds of the Pottsville laid down in the same sea. During Pottsville time, as well as later in the Pennsylvanian, the basins of sedimentation in the eastern United States stood alternately slightly above and slightly below sea-level. Continental clastic materials and peat accumulated while this region existed as land, and fossiliferous limestones and shales record marine inundations. During Pottsville time an epi-continental sea advanced into and retreated from Ohio at least ten times, and these advances of marine waters are recorded by ten marine fossiliferous horizons, which are invariably separated from each other by coal beds. In western Illinois there were at least six distinct marine invasions separated by intervals of land conditions during Pottsville time. Likewise, wherever Pottsville beds are exposed on the borders of the northern half of the Western Interior basins, similar alternating marine and terrestrial conditions are plainly indicated. Somewhere in the direction from which the invading waters came, a permanent Pottsville sea existed, but its position is not yet known. The careless use of such expressions as the *Pottsville sea* or, still worse, the *Pennsylvanian sea* seems to imply that conditions and environments of Pennsylvanian sedimentation were much more uniform and Pennsylvanian history was much less eventful than they are known to have been, and should be avoided.

J. MARVIN WELLER

URBANA, ILLINOIS
February 27, 1931

RECENT SUBSIDENCE, HAMILTON COUNTY, KANSAS

I was very much interested in the description of the "Recent Subsidence in Hamilton County, Kansas," by N. W. Bass[1]. I am in perfect accord with most of the facts and theories given in this paper, but my observations lead me to correct the statement ". . . . beds of chalky limestone and calcareous shale belonging to the Fairport chalky shale member of the Carlile shale of Upper Cretaceous age are exposed in the road bordering it (the sink) on the east and in the hillside a few hundred feet north of the sink hole" (p. 204), and to the conclusion, based on this statement, that the original cavern was formed in Greenhorn limestone. In the company of M. K. Elias of the Kansas Geological Survey staff I visited the Hamilton County sink on April 10, 1931. The walls of the hole have recently slumped in to such an extent that the public road has been engulfed across its entire width. Ten feet of Graneros shale is exposed on the side of the sink beneath the former position of the road. This slumping occurred after Bass's visit. The top of the exposed Graneros is 13 feet below the rim of the sink and exposures continue down to and undoubtedly below the present level of the water partly filling the hole. As the Graneros is overlain by alluvium, the top of the exposure is not necessarily the top of the formation. The identification of this shale as Graneros was checked by the finding of a 2-inch bed of dark coarsely crystalline limestone emitting a petroleum odor exposed in a small gulley a short distance northeast of the sink. This limestone is characteristic of the Lincoln, the lowest member of the Greenhorn formation. The limestones and calcareous shales described by Bass as lower Carlile lie in the 15 feet immediately above this Lincoln bed. He states that "the age of exposed rocks is based on the lithology and fossils which were identified in the field by J. B. Reeside, Jr., of the United States Geological Survey, as *Inoceramus fragilus*, a Carlile species" (p. 204). Chalky limestones and calcareous shales are found both in the Greenhorn and in the lower Carlile. *Inoceramus fragilus* is not confined to the Carlile, but also occurs in the Greenhorn and is reported by Darton in the Graneros.[2] The limestones and calcareous shales described by Bass lie well below the top of the Greenhorn.

Undoubtedly the original cavern was formed in pre-Dakota strata, because very little soluble rock is found in the Graneros or Dakota formations. Roy Hall has called the writer's attention to a well in eastern Colorado about 45 miles northwest of the Hamilton County sink which encountered 100 feet of gypsum probably of Triassic age.[3] Bass, in a stratigraphic section based in large part on the log of a well drilled about 10 miles east of the sink, notes the presence of "lime, probably anhydrite" in the upper part of the Permian (?). Several beds of salt were logged between 1,200 and 1,500 feet, likewise in the Permian (?) (p. 203).

It is the writer's conclusion that dissolution of soluble pre-Dakota strata, possibly salt but more probably gypsum, caused the formation of the original cavern underlying the Hamilton County sink.

KENNETH K. LANDES

KANSAS GEOLOGICAL SURVEY
LAWRENCE, KANSAS
April 17, 1931

[1]*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 2 (February, 1931), pp. 201-05.
[2]N. H. Darton, "Syracuse-Lakin Folio," *U. S. Geol. Survey Folio 212* (1920), p. 5.
[3]Informal communication.

E. McKENZIE TAYLOR'S GENESIS OF PETROLEUM AND COAL AS APPLIED TO FRUITVALE FIELD, CALIFORNIA

A recent series of papers by E. McKenzie Taylor, lecturer in agricultural chemistry, University of Cambridge, dealing with the subject of base exchange and its relation to the genesis of coal and petroleum, presents some factors of interesting and probably valuable geological application.[1]

The view advanced by Taylor is that when organic matter is deposited with sedimentary beds, the factor that determines whether it is to be preserved as coal, or oil, or decomposed and its decomposition products dissipated, depends on whether or not the organic deposit is sealed over or capped by impermeable material. The process by which the sedimentary materials that cover the organic deposits become impermeable and thus preserve those deposits in the form of coal or oil is explained as involving the chemical reactions known as base exchange.

It is assumed that in order to preserve the organic material from which coal or oil is ultimately to be formed, two conditions must be met: (1) the covering material must exclude atmospheric air, because the decomposition must be of a reducing rather than of an oxidizing character; and (2) the solution in contact with the decomposing organic material must be kept alkaline to neutralize the acidic decomposition products. These conditions are provided when, as the result of base exchange reactions, the clay of the overlying sediment contains a preponderance of replaceable sodium. Taylor has found by the analysis of specimens of the sedimentary rock covering deposits of coal and oil, that these contain much more replaceable sodium than calcium, and has shown by laboratory experiments that when organic matter in wet sediment decomposes, with air excluded and the solution kept alkaline, the decomposition product resembles coal.

The processes of base exchange, by which the chemical composition and the physical properties of soil or of sedimentary rocks are so profoundly influenced, have been the subject of intensive investigations by soil chemists during the past decade. It has been shown that the clay and silt fractions of sedimentary material possess the same property of base exchange as do the zeolitic materials used so extensively as water softeners. Furthermore, it has been demonstrated that, when clay or silt has been suspended or submerged in a solution of a sodium salt and subsequently leached with pure water, it becomes deflocculated, and when later consolidated, as by pressure or dehydration, it becomes impermeable to the movement of water, gas, or air. Thus, silt deposited in ocean water, as at a stream delta, would, by the reaction of base exchange, yield its replaceable calcium and magnesium and become sat-

[1] "The Bearing of Base Exchange on the Genesis of Petroleum," *Jour. Inst. Petrol. Tech.*, Vol. 14, No. 71 (December, 1928), pp. 825-40.

"The Replaceable Bases in the Shales and Clays Overlying Petroliferous Strata," *Jour. Inst. Petrol. Tech.*, Vol. 15, No. 73 (April, 1929), pp. 207-10.

"A Comparison of the Conditions of Occurrence of Bituminous Coal and Petroleum," *Jour. Inst. Petrol. Tech.*, Vol. 15, No. 74 (June, 1929), pp. 372-84.

"Base Exchange Between Clay and Solutions of Sodium Salts and Its Relation to the Formation of Coal and Petroleum," *South African Jour. Sci.*, Vol. 26 (December, 1929), pp. 57-69.

urated with sodium in the same way that the zeolite of a water softener yields the calcium and magnesium it has absorbed from hard water when it is "revivified" from time to time by treatment with a solution of sodium chloride. If such a deltaic deposit of silt is subsequently raised above the ocean and the soluble salt is leached from it by rain water, it becomes dispersed or deflocculated; consequently, impermeable. If, on the other hand, after its emergence from the ocean it is leached by fresh stream waters containing calcium and magnesium salts, even in low concentrations, the combined sodium may be gradually replaced by the alkaline-earth bases and a permeable physical condition may be caused. Or, if sediment is deposited in fresh water in which the salts are preponderantly those of calcium and magnesium, it remains flocculated and permeable, even though it is subsequently leached by rain water.

One further factor remains to be considered: when the soil or a sedimentary deposit is subjected to leaching by rain water, exchange reactions occur after the soluble salt has been leached away. By these exchange reactions the hydrogen ion of the water gradually replaces the bases from the clay complex. This process is sometimes referred to as hydrolysis rather than base exchange. By that reaction the hydrogen ion from the water combines with the clay and the replaced ion, sodium or calcium, passes into solution to balance the hydroxyl ion of the water, thus forming sodium hydroxide or calcium hydroxide. If the basic ion so replaced from the clay is chiefly sodium, the resulting solution containing sodium hydroxide is more alkaline than if calcium is replaced. Thus, a sedimentary cover of sodium clay not only forms an impermeable seal over the decomposing organic matter, but it yields a supply of sodium hydroxide to neutralize the acidic products of that decomposition and permits the reduction to proceed to the end, which may be the carbon of coal or the hydrocarbons of oil.

In addition to offering an explanation as to how sedimentary deposits may form an impermeable cap or seal over submerged deposits of organic matter and provide the alkalinity necessary to their partial decomposition, Taylor proposes a theory as to why the decomposition product is in some places petroleum and in some, coal. Briefly, this theory is that where the organic matter in the buried sediments is chiefly of aquatic or marine origin and thus does not contain lignin, the decomposition product is petroleum. On the contrary, where the organic matter is chiefly of terrestrial origin and contains lignin, the decomposition product is coal.

In regard to coal deposits, Taylor believes that the type of cover determines the type of coal. Where the cover is impermeable and alkaline in reaction (sodium clay), black coal, bituminous or anthracite, is formed. If the cover is permeable and neutral in reaction (calcium clay), brown coal (lignite) is formed.

These views may be summarized as follows. Organic matter of aquatic or marine origin decomposing in sediments under an impermeable alkaline cover, forms petroleum. Organic matter of terrestrial origin containing lignin, decomposing in sediments, forms coal. If the cover is impermeable and alkaline, black coal is formed; if the cover is somewhat permeable and neutral in reaction, brown coal is formed.

The foregoing analysis of Taylor's views is the outcome of conversations between the writers of this review, which were prompted in the beginning by a suggestion of possible application of some of the principles involved to California oil-field problems. This refers particularly to the accumulation of oil and gas in the Union Avenue and Fruitvale areas in the southeastern part of San Joaquin Valley, including also the so-called Kern Front, and possibly the old Kern River field itself.

In the Kern Front and Fruitvale areas, most of the productive oil zones lie immediately below a distinct section of marine beds, so that these marine beds seem to be causally related to the accumulation of the oil. This marine section, which is approximately 300 feet thick at Fruitvale, seems to thicken westward toward the center of the San Joaquin Valley, and is believed to thin in a general way eastward, indicating the farthest extension in this direction of a marine transgression which occurred during the lower Pliocene (Jacalitos) time in this region. The beds above these fossiliferous marine deposits are seemingly fresh-water fluvial or land-laid deposits, being in many places banded or mottled with dull reds and browns, suggesting deeply oxidized soil products, and many fragments of mammalian bones have been recovered in the well cores. Similar land-laid deposits 1,000 feet or more thick are found below the Pliocene marine section, and coarse granitic or arkosic sands in the upper part of this lower land-laid section are the oil-containing beds. Marine Miocene underlies the section described.

In this part of the San Joaquin Valley it may be assumed that the oil originated from organic material first contained in marine Tertiary deposits, probably of middle Miocene (Temblor) age, but the oil may have been derived in part from lower Pliocene (Jacalitos) age deposits, the latter being an alternating succession of fresh or brackish and marine zones in the central part of the San Joaquin Valley grading into or interfingering with the land-laid beds around the margin of the basin.

It is not at all certain that the lower Pliocene marine beds in the Fruitvale and Kern Front areas formed the capping of the deposits which produced the oil, but, at least, these marine beds seem to constitute the retaining member which is the direct cause of the productive oil accumulation. It seems probable that the impermeable sodium clays, deposited in ocean water, subsequently leached by fresher ground waters, deflocculated and consolidated by pressure, have produced the impermeable capping necessary to retain the oil. Suggestive source beds are not found in the 1,000 feet of land-laid deposits that preceded the Pliocene marine section in the Fruitvale field. Faulting is a conspicuous feature of this general section, and there is little doubt that the oil has migrated along these fracture zones, and was retained only where the effective seal was produced.

Essentially the same conditions prevail in the Union Avenue district 5 miles southeast of the Fruitvale field, except that, from the evidence of tests that have been drilled to date, neither oil nor gas seems to exist in that locality in pools of commercial quantities. Oil and gas sands were found in a considerable series in some of the wells drilled in the Union Avenue area, the highest being at approximately the depth of the marine beds of the near-by Fruitvale area. A few marine fossils in a thin, almost insignificant wedge of shale and

sandy beds are the only evidence of a marine section at Union Avenue. There is evidence of faulting, and a suggestive low doming in the surface formations indicates that the structure alone may be considered favorable for the accumulaton of oil. Lack of an adequate marine section to effect a seal may, therefore, be the defect in the Union Avenue area that prevented it from becoming an oil field. The Pliocene sea, which covered the Fruitvale area while 300 feet of deposits were laid down there beneath its waters, seems to have reached its farthest extension in a southeasterly direction at approximately the position of the Union Avenue area.

HOYT S. GALE and
C. S. SCOFIELD

LOS ANGELES, CALIFORNIA
and
LANHAM, MARYLAND
April, 1931

REVIEWS AND NEW PUBLICATIONS

Les méthodes de prospection du sous-sol. By E. ROTHÉ. (Gautier-Villars et Cie., Paris, 1930. May be obtained from G. E. Stechert and Company, 33 East Tenth Street, New York.) 392 pp., 156 figs. Price, $3.75.

Another addition to the library of geophysical literature comes from Strasbourg. It is written from a new angle and is distinctly reminiscent of the laboratory manuals of college days.

The book is divided into four parts, dedicated to magnetic, electric, seismic, and gravitational methods. Under each of these methods there is given first a brief explanation of theory and apparatus, then a detailed guide to "manipulations," and finally a discussion of the application of the method. The treatment of the electric method is very limited as, the author explains, it is already well known and widely used in France.

The author avowedly stresses the practical application of his subject. Where the language is not a barrier, his logical tabulations should be very helpful to the student. Those already familiar with geophysical methods will be disappointed at the lack of theoretical discussion.

MARGARET C. COBB

NEW YORK, NEW YORK
April 16, 1931

"The Geology of Some Salt Plugs in Laristan (Southern Persia)." By JOHN VERNON HARRISON. *Quar. Jour. Geol. Soc.*, Vol. 86, Pt. 4, No. 344 (December, 1930), pp. 463-522, 19 figs., 7 pls., bibliography.

This paper is a most interesting description of twenty-nine of the approximately one hundred and seven salt domes of Persia. Detailed sketch geologic maps are given for seventeen of the domes, and a colored geologic map for the whole area accompanies the article.

Ordovician to Quaternary formations are exposed with no general angular unconformity below the Pliocene and attain a maximum thickness of 25,000 feet. The pre-Miocene section is predominantly limestone. The Plio-Miocene section is predominantly silt, shale, sandstone, and subordinately limestone. The salt has brought up the Hormuz series, a heterogeneous jumble of rocks, some of which are not known to crop out elsewhere than on the domes, some of which resemble rocks of the Salt Range of India, and some of which carry middle Cambrian fossils. The age of the salt is regarded as Cambrian or possibly pre-Cambrian.

An overthrust nappe bounds the salt dome area on the north and east. The overthrusting was late Miocene or Pliocene in age. The foreland is a succession of elongated anticlines in which the Cretaceous has been brought up to

the surface through the Tertiary. The anticlines tend to have an approximately east-west trend; therefore, to be sub-parallel with the edge of the overthrust at the north.

Many of the domes have pierced the crests of the anticlines, but in most places they are at the plunging ends of anticlines. A few have broken through the flank, quite abruptly on the north or the south flank, and a few seem to have no relation to the anticlines. The plan of most of the domes other than those immediately at the edge of the nappe is circular or sub-circular. Generally, no alignment of the domes is evident. The intrusion of the salt has accompanied one or another of the several movements which have disturbed this area since mid-Cretaceous time; the chief intrusion accompanied the major tectonic movements which were late Miocene or Pliocene. Some domes presumably have not risen much for a long time; the Zangur dome has a 4,000-foot central topographic depression from which a corresponding amount of salt has been dissolved. Other domes seem to have risen in recent times; the Kuh-i-shur dome rises 4,000 feet above the surrounding plain and well above the surrounding rim rocks. Some of the domes seem to have formed islands in the Miocene seas, as several domes in the present Persian Gulf.

The much discussed "salt glaciers" range from little more than local steep saline rock falls to great flat tongues stretching out far from the actual salt hill. The material of the salt glacier of the tongue type is chiefly salty gypsum with clay.

The rare boulders of metamorphic rocks which have been brought up by the salt are explained by the supposition that they are fragments torn from the floor of the salt bed.

The origin of the domes is ascribed partly to tangential thrust and partly to the static vertical pressure of the overlying beds. The "relief of pressure by the erosion of the crest of anticlines" mechanism is suggested.

The interpretation of the salt glaciers seems to the reviewer to require further examination. He accepted Richardson's interpretation of them and would like very much to be able to use them as evidence of the flowage of salt under moderate pressure and surface temperature. But Harrison's descriptions of them have disquieted the reviewer, who wonders if it is safe to postulate that the flowage in the salt glaciers is a flowage comparable with the internal flowage of salt in the formation of the salt domes. The description of the tongue type of "salt glacier" as composed primarily of salty gypsum with clay suggests a gypsum "mud" flow, perhaps of residual gypsum.

The few metamorphic fragments among the débris brought up by the salt and the overthrust nappe at the north edge of the salt dome area cause the reviewer to wonder if sufficient consideration has been given to the possibility that the Cambrian rocks have been picked up from overthrust nappes and to the possibility that the salt is not Cambrian or pre-Cambrian. Voitesti postulated a pre-Cambrian age for the Roumanian salt on the evidence of the pre-Cambrian blocks brought up by the salt; the general consensus of opinion seems to be, however, that salt plucked those pre-Cambrian rocks from overthrust nappes.

An American geologist would have difficulty in recognizing the North American salt domes in the description of them as "occurring east of the

Rocky Mountains from Mexico nearly to Canada" and as occurring "in the quiet, thickly covered edge of a foreland in a sickle-shaped bow formed by the front of thrust mountains."

This paper is an important contribution to the geology of salt domes and should be read by every geologist interested in the theory of salt domes. Its descriptions of the interesting phenomena so well exposed is most tantalizing to a geologist who is far away from Persia.

DONALD C. BARTON

HOUSTON, TEXAS
April 15, 1931

The Oil Exploration Work in Papua and New Guinea Conducted by the Anglo-Persian Oil Company on Behalf of the Government of the Commonwealth of Australia, 1920-1929. (London, 1931.) 4 volumes quarto, illustrated. Colored geological maps and sections. Price, £10.

The anxiously awaited report of the Anglo-Persian Oil Company on the results of the geological surveys conducted by it on behalf of the Commonwealth Government in Papua and New Guinea has come to hand. It fills four large quarto volumes of text and two of maps. That this mass of material should have been assembled and published so quickly is a tribute to the energy of its editor, B. K. N. Wyllie.

The first volume opens with a foreword from the pen of Sir John Cadman, chairman of the Anglo-Persian Oil Company. This is followed by a historical outline, by B. K. N. Wyllie; reports of the first geological expedition, 1920-1923, by various authors; and of drilling operations at Popo, 1922-1929, by B. K. N. Wyllie.

Volume 2 consists of reports of the second geological expedition, 1927-1929: Oriomo, Cape Vogel, Barum River, Sepik, Hansemann Coast, by various authors.

Volume 3 contains the reports of the second geological expedition, 1927-1929: Finsch Coast, by J. Nason-Jones.

Volume 4 contains a contribution to the Tertiary geology of Papua, by J. N. Montgomery; a brief review of the oil prospecting work at Upoia, 1911-1920, by J. N. Montgomery; and last but by no means least, a critical study of the geology and oil prospects of Papua and New Guinea as revealed by the work of the Anglo-Persian Oil Company, 1920-1929, by B. K. N. Wyllie.

Volumes 5 and 6 consist of maps and sections, admirably executed and reproduced in color.

The whole report forms one of the great contributions to geological literature in recent years and reflects much credit upon all concerned in its production. Unfortunately, for many reasons, its very excellence results in its being very costly and the published price amounts to £10, which puts it out of reach of most individuals and institutions in Australia.

Naturally, for most people in Australia the burning question is: "What hopes of obtaining oil are held out by the investigations?" The reply is disappointing in the extreme. The report is almost completely adverse in this respect.

In his admirable critical review, Mr. Wyllie calls attention to the analogies of the oil fields of the East Indies and indicates that, in these areas, the *productive* oil fields are confined to the newer Tertiaries (Neogene). In both territories the structures in rocks of this age are believed to be too much eroded and too fragmentary to hold out much hope of success. It is believed that the chances of finding more than traces of oil in the older Tertiaries are small. Mr. Wyllie's reasoning is close and logical, and must be accepted as a very serious setback to the hopes which have been advanced of successful oil search in New Guinea.

If a criticism can be leveled at these conclusions, it is that they are founded upon sharply defined theory, which, though plausible, has not as yet been completely proved. Admittedly also, analogies between oil fields are somewhat dangerous. So many factors enter into the question that each area constitutes a problem in itself and must be examined individually. That Mr. Wyllie recognizes this is shown by his frequently reiterated advice that much more preliminary research should be undertaken in that part of New Guinea which is under Australian jurisdiction before any deep drilling campaign is begun.

His final summary of the position is here quoted in part.

> This review ends, therefore, with a note of pessimism. Some possibilities have been admitted, in regions not yet fully (or even partially) explored; but in the main, the hopes entertained by the earlier geologists have been rejected.
>
> ....fresh starting points from which research would appear likely to obtain valuable clues are here summarized:....(1) the belt of country northwest and southeast of Nalopo Island in the Purari River, the sharply folded hill country to northeast and the swamp region to southwest (which may be less extensive than is shown on existing maps, and may possibly yield topographic structure-clues; (2) the southern coast of Goodenough Bay and the Roaba Valley; (3) the middle Ramu Valley, in the region of the Arumene Hills; and (4) the country on the south side of the Torricelli Range, wherever best approachable.

W. G. Woolnough

Department of Home Affairs
Canberra, F. C. T., Australia
April 9, 1931

RECENT PUBLICATIONS

CANADA

"Oil and Gas Prospects in Central Saskatchewan," by P. S. Warren. *Canadian Dept. of Mines, Geol. Survey, Summary Report, 1929, Part B* (Ottawa, Canada, 1930), pp. 40-47.

"Overthrust Faulting and Oil Prospects, Eastern Alberta Foothills," by G. S. Hume. *Econ. Geol.*, Vol. 26, No. 3 (Urbana, Illinois, May, 1931), pp. 258-73, 6 figs.

EUROPE

Economic Geography of Europe, by W. O. Blanchard and S. S. Visher. (McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York, New York, 1931.) 507 pp., 331 figs., 1 pocket map. Price, $3.50.

Erdöl. Allgemeine Erdölgeologie und Überblick über die Geologie der Erdölfelder Europas, by O. Stutzer. (Gebrüder Borntraeger, Schöneberger Ufer 12a, Berlin W. 35, Germany, 1931.) Price, bound, approximately 55 RM.

GENERAL

Allgemeine Erdölkunde für Industrie und Handel, by C. Koettnitz. (Wilhelm Knapp, Halle (Saale), Germany, 1931.) 143 pp. Price, paper, 8.30 RM.; bound, 9.80 RM.

Diskordanz und Orogenese der Gebirge am Mittelmeer, by Wilfried Seidlitz. (Gebrüder Borntraeger, Schöneberger Ufer 12a, Berlin W. 35, Germany, 1931.) 651 pp., 15 tables, 140 illus. Price, paper, 72 M.; cloth, 75 M.

"L'origine du pétrole," by Leon Bertrand. *Annales de l'Office National des Combustibles Liquides,* No. 6 (Paris, November-December, 1930), pp. 926-48. 6 figs.

GERMANY

Deutches Erdöl, by A. Bentz, Rudolf Herrmann, A. Kraiss, and Otto Stutzer. Edited by Otto Stutzer; introduction by Stutzer. Contains the following: "Der mesozoische Untergrund der norddeutschen Flachlandes und seine Erdölhöffigkeit," by A. Bentz; "Die geologie der Ölkreide von Heide in Holstein," by A. Kraiss; "Die Erdöllagerstätte von Oberg bei Peine," by Rudolf Herrmann. (Ferdinand Enke, Stuttgart, Germany, 1931.) 150 pp., 27 illus. Price, 18 RM.

MONTANA

"Geology of the Big Snowy Mountains, Montana," by Frank Reeves. *U. S. Geol. Survey Prof. Paper 165-D* (Supt. Documents, Washington, D. C.), pp. 135-49, Pls. 35-38. Price, $0.20.

RUMANIA

1. "Quelques nouvelles données sur la genese du pétrole des régions Carpathiques Roumaines." 2. "Sur la stratification de la glace des glaciers, son rôle et ses déformation dans le mouvement d'advancement." By I. P. Voitesti. *Revista Muzeului Géologic-Mineralogic de l'Université de Cluj* (Roumanie), Vol. 4, No. 1 (1930). 25 pp., 3 figs.

SOUTH DAKOTA

The South Dakota Geological and Natural History Survey, Vermillion, South Dakota, announces the following mimeographed publications.

"The Fairburn Structure," by E. P. Rothrock. *Report of Investigations No. 6* (October, 1930). 12 pp., 3 figs.

"The Cascade Anticline," by E. P. Rothrock. *Report of Investigations No. 8* (February, 1931). 19 pp., 5 figs.

"The Chilson Anticline," by E. P. Rothrock. *Report of Investigations No. 9* (March, 1931). 26 pp., 7 figs.

UNITED STATES

"Petroleum Industry of the Gulf Southwest." Part II of the Commercial Survey of the Gulf Southwest. *Domestic Commerce Series 44* (Supt. Documents,

Washington, D. C.). The area of Texas, Oklahoma, Kansas, Louisiana, Arkansas, New Mexico, Mississippi, and Missouri produces 43 per cent of the world's petroleum output, 65 per cent of the United States' output. 252 pp., 67 figs., several maps. Price, $0.65.

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Memorial

THOMAS MOIR GARDINER, JR.

It is with deepest sorrow that we chronicle the death of Thomas Moir Gardiner, Jr., on January 23, 1930, at Bakersfield, California. He contracted lobar pneumonia on Sunday and died the following Thursday.

Mr. Gardiner's pleasing personality and sterling character had won for him a wide circle of intimate friends. Though young in years, his judgment was that of maturity, and as a comrade and adviser he was esteemed by all. It is a matter of very great regret to his many friends, that one whose future promised so much should be so suddenly removed by an untimely death from a life-work just commenced.

Mr. Gardiner was born in Oakland, California, in 1898, and attended the grammar and Fremont High School of that city.

Shortly after the United States entered the World War, he enlisted in the U. S. Naval Reserve Force, and saw active duty in the Panama Canal Zone as a boatswain's mate, first class. Following his discharge in 1919, he entered the New Mexico School of Mines and graduated from that institution with the B. S. degree in 1923. He then entered the University of California as a graduate student in geology and stayed there during the years 1923 and 1924. During his student days, he became a member of the Phi Kappa Psi and Theta Tau fraternities.

From November, 1924, to April, 1925, he was employed as assistant geologist with the California Petroleum Corporation. From April, 1925, to the date of his death, he was employed by the Shell Oil Company on its exploration staff in the Bakersfield office.

Mr. Gardiner was elected to associate membership in The American Association of Petroleum Geologists in February, 1926, and was transferred to active membership in September, 1928. He was a charter member of the affiliated Society of Economic Paleontologists and Mineralogists.

Mr. Gardiner is survived by his father and mother, a brother, his wife, Mildred Taylor; and his two children, Thomas Moir III and Charles Taylor.

ARTHUR R. MAY

BAKERSFIELD, CALIFORNIA

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

W. F. Knode, Jr., is at present connected with the Hobbs proration office as petroleum engineer. His address is Box 665, Hobbs, New Mexico.

L. C. Chappuis announces that his new office address is 617 Pacific National Building, Los Angeles, California. He is to have charge of the geological and engineering department of the recently organized Kettleman Hills Petroleum Syndicate. Although affiliated with this company, Mr. Chappuis will still continue his practice as a geologist and petroleum engineer.

Francis W. Lake, of the Union Oil Company of California, Santa Fe Springs, California, has an article in the April 23 issue of *The Oil and Gas Journal* entitled "Is Cost Accounting of Any Real Value in Oil Field Operations?"

J. H. Turner and Chester D. Whorton, consulting geologists, 406 Milam Building, San Antonio, Texas, will be associated for the summer with the Pennsylvania Power and Light Company, Box 236, Wellsboro, Pennsylvania.

K. H. Schilling, formerly of the Shell Petroleum Corporation at Dallas, Texas, is with the same company at Muskegon, Michigan. His post office address is Box 439, Muskegon.

M. M. Kornfeld is micropaleontologist for Oil Well Sample Service, Tulsa, Oklahoma.

The organization committee of the 16th International Geological Congress has decided to postpone the Congress to the last of June, 1933, in Washington.

Paul D. Torrey, consulting geologist, of Bradford, Pennsylvania, gave a series of lectures on petroleum geology at Pennsylvania State College and at Princeton University in April.

L. L. Foley addressed the Tulsa Geological Society, April 20, 1931, on "A New Theory of Earth Deformation and Application to the Mid-Continent Region."

T. P. Gore, Oklahoma senator, states that Oklahoma is entitled to 732 federal employees in the civil service in the District of Columbia. Oklahoma has only 204 now employed in the District. Perhaps other states do not have their full quota. The Civil Service Commission sends all Association members and associates notices of examinations to be held for vacancies in government positions in geology and related subjects.

The Massachusetts Institute of Technology, Cambridge, Massachusetts, offers special courses in petroleum refining during the summer session, July

20 to August 21, 1931. Further information may be obtained from the Department of Chemical Engineering.

The private laboratory of HANS LÖFFLER, Anastasius Grüngasse 48, Vienna, XVIII, has been accorded official authorization by the State Ministry of Commerce and Transport, as Institute of Fuel Research and Gas-Engineering.

E. O. ULRICH, of the United States Geological Survey, and R. S. BASSLER, of the United States National Museum, are co-authors of "Cambrian Bivalved Crustacea of the Order Conchostraca," issued as Publication No. 2847 by the Smithsonian Institution.

FREDERICK G. TICKELL, professor of petroleum engineering at Stanford University, is the author of a new book entitled *The Examination of Fragmental Rocks*, published by the Stanford University Press.

The Panhandle Geological Society, Amarillo, Texas, recently elected the following officers for the ensuing year: president, J. D. THOMPSON, JR., consulting geologist; first vice-president, H. T. MORLEY, Stanolind Oil and Gas Company; second vice-president, J. V. TERRILL, Gulf Production Company; and secretary-treasurer, A. R. KAUTZ, Empire Gas and Fuel Company.

The papers and discussions on "The Age of the Producing Sands on the East Rim of the East Texas Basin," as presented at a meeting of the Dallas Petroleum Geologists at Dallas, Texas, on March 7, 1931, are now available for distribution. The data, including maps, have been compiled in the form of a mimeographed report which may be obtained from Dallas Petroleum Geologists, 306 Magnolia Building, Dallas, Texas, at the price of $0.75 postpaid.

G. A. WARING, of Tulsa, Oklahoma, is with the U. S. Geological Survey in the investigation along the Alaskan Railway. This work, which is connected with the development of the coal and other mineral resources contributory to the railroad, will require 4 months in the field and the winter in Washington, D. C.

V. V. WAITE, of Dallas, Texas, has formed a partnership with Taylor Fithen and George W. Smith, under the name of Taylor Fithen and Company, Engineers and Geologists. Their office is at the Blackstone Hotel, Tyler, Texas.

CHARLES M. ROSS, formerly head of the geophysical department, Stanolind Oil and Gas Company, Tulsa, is now with the Geophysical Research Corporation. His address is Box 2022, Tulsa, Oklahoma.

W. E. BAKKE, formerly of the Shell Petroleum Corporation, at Oklahoma City, Oklahoma, is now employed in the geological department of the North Penn Gas Company, at Port Allegany, Pennsylvania.

W. H. TWENHOFEL, of the University of Wisconsin, succeeds ARTHUR KEITH, on July 1, as chairman of the division of geology and geography of the National Research Council. Professor Twenhofel is to be on sabbatical leave during the second half of the year.

The Tulsa Geological Society, in its meeting of May 4, 1931, held a symposium on a few South American countries. The following countries were discussed: "Peru," by G. S. LAMBERT, assistant chief geologist, Phillips Petroleum Company, Bartlesville, Oklahoma; "Brazil," by G. A. WARING, of the U. S. Geological Survey; and "Argentina," by ROBERT H. DOTT, geologist of Tulsa.

The Third International Drilling Congress, originally scheduled for 1931, has been postponed until 1933. It will be held probably in September in Kroll's Establishment at the Platz der Republik. All inquiries should be addressed to M. Laubsch, secretary of the German National Committee, Berlin, S. W. 68.

The complete 10-Volume Index of the *Bulletin* (1917-1926), which originally sold at $2.00 per copy, is now available at Association headquarters at a special price of $1.00. This is not merely a list of papers and authors in each year's *Bulletin*, but is a complete detailed, topical, geologic, geographic, subject, author reference key to the first ten volumes.

C. L. COOPER, formerly chief geologist of the Oklahoma Geological Survey at Norman, Oklahoma, has accepted a position with the Kentucky Geological Survey at Frankfort, Kentucky.

CHARLES E. STRAUB, consulting geologist and operator of Wichita, Kansas, is at 618 Fuhrman Avenue, Bellevue, Kentucky.

IONEL I. GARDESCU, assistant professor in petroleum engineering at the University of Pittsburgh, has received the degree of doctor of philosophy from the University of California. His thesis was "The Occurrence and Behavior of Natural Gas in an Oil Reservoir."

Copies of *Structure of Typical American Oil Fields*, Vols. I and II, are still available at Association headquarters. Members and associates will have an opportunity to purchase one copy of each at the special price of $4.00 until January 1, 1932. After that time, the price of Vol. II will be $7.00 ($5.00 to members and associates).

G. E. WHEELER, formerly district geologist for the Nordon Corporation, Ltd., at Calgary, is now attending Columbia University, New York City, where he is taking work toward a Ph. D. degree in structural geology. His address is 780 St. Mark's Avenue, Brooklyn, New York.

ADDISON YOUNG, geologist, 3312 Highland Place, N. W., Washington, D. C., has an article in the May 1, 1931, issue of *The Oil Weekly*, entitled "A Method for Determining Correct Spacing for Wells with Special Reference to West Texas."

G. S. HUME, of the Geological Survey of Canada, Ottawa, Canada, presented a paper on "Gas Prospects in the Prairie Provinces of Canada" before the twenty-fourth annual convention of the Canadian Gas Association, held at Montreal, June 4 and 5, 1931. R. B. HARKNESS, Whitney Block, Parliament Buildings, Toronto, presented a paper on "Natural Gas in Ontario."

LOUIS C. CHAPPUIS, consulting geologist, with offices at 617 Pacific National Building, Los Angeles, California, has a brief article in the May, 1931, issue of the *Oil Bulletin*, entitled "Prospecting for Oil in Peru." The article presents a summary of Peruvian mining laws.

R. A. BROOMFIELD, JR., has been appointed manager of the land department of the Barnsdall Oil Company of California, at Los Angeles, California.

JOSEPH E. POGUE, 42 West Twelfth Street, New York City, addressed the Chamber of Commerce of the United States, at Atlantic City, April 29, 1931, on "Waste and Production Control." The address is published under the same title in the May, 1931, issue of *World Petroleum*.

R. CLARE COFFIN, of the Midwest Refining Company, Denver, addressed the Rocky Mountain Association of Petroleum Geologists, May 7, 1931, at Denver, Colorado, on the subject, "Scientific Research as Applied to Problems of the Petroleum Geologist."

JOHN F. DODGE, professor at the University of Southern California, Los Angeles, California, has an article on "Methods of Straight Hole Drilling," in *World Petroleum* for May, 1931.

J. W. BEEDE's address is Route 1, Bloomington, Indiana.

J. FRENCH ROBINSON, geologist and engineer, Hope Natural Gas Company, Pittsburgh, Pennsylvania, is the author of a brief article in the May 14 issue of *The Oil and Gas Journal*, entitled "Surface Conditions Important in Selecting Drilling Site in East."

DAVID DONOGHUE, 1116 Fort Worth National Bank Building, Fort Worth, Texas, resigned, effective May 1, as technical adviser to the Texas State Central Proration Committee.

W. M. RAU has severed his connection with the Republic Petroleum Company, Ltd., and is carrying on independent work. His address is Box 472, Long Beach, California.

MARVIN LEE, geologist, 612 Brown Building, Wichita, Kansas, has been elected president of the Kansas division of the Independent Petroleum Association of America.

VIRGIL R. D. KIRKHAM, of Saginaw, Michigan, has an article in the April-May, 1931, issue of *The Journal of Geology* on "Revision of the Payette and Idaho Formations."

ANDREW C. LAWSON, of the University of California, Berkeley, California, has an article on "The Isostasy of the Uinta Mountains" in the April-May issue of *The Journal of Geology*.

HAROLD VANCE and VERNE FAGIN, of Vance-Fagin Engineering Company, consulting petroleum engineers, Kilgore, Texas, have an article on "Producing Conditions in New Sabine Uplift Region of East Texas" in the May issue of *International Petroleum Technology*.

BASIL B. ZAVOICO spoke before the Tulsa Geological Society, May 18, 1931, on "Russia—Her Five-Year Plan and Her Oil Fields."

W. GRANT BLANCHARD, JR., consulting geologist, has his office at 812 Dallas Bank and Trust Building, Dallas, Texas.

E. M. CLOSUIT, of the Southern Union Gas Company, has recently moved from Fort Worth to the company headquarters at 703 Browder Street, Dallas, Texas.

ALFRED C. BIERMAN, with the Fain-McGaha Oil Corporation, has been transferred from Wichita Falls to the Tyler, Texas, office of the company.

ORVAL L. BRACE, formerly of Corsicana, has moved to Tyler and has his office in the Swann Building. He is associated with the E. L. Smith Oil Company.

CHARLES I. JENNINGS is associated with the Salmar Oil Corporation as a director and geologist, with offices in the Citizens National Bank Building, Tyler, Texas.

EDGAR KRAUS, formerly district geologist for the Atlantic Oil Producing Company at San Angelo, Texas, has been transferred to Carlsbad, New Mexico, as geologist for southeast New Mexico.

ALFRED GRAY, formerly geologist for the Atlantic Oil Producing Company in Carlsbad, New Mexico, has been transferred to East Texas.

P. R. YEWELL, consulting geologist of San Angelo, has gone to Alpine, Texas, for two months' field work, after which he will move his residence to California.

On May 16, 1931, a party of twenty West Texas geologists led by R. L. CANNON and JOE CANNON studied outcrops of the San Angelo conglomerate in Coke County 20 miles northeast of San Angelo.

MORGAN ROBERTS, district geologist for The Pure Oil Company in West Texas, has moved his residence from San Angelo to Odessa, Texas.

N. P. ISENBERGER, formerly geologist at Beaumont for the Superior Oil Company of Oklahoma, has resigned his position with that firm and is now engaged in consulting work in San Angelo, Texas. His address is 118 North Monroe Street.

C. I. JENNINGS, consulting geologist, formerly at San Angelo, has moved his residence to Tyler, Texas.

F. K. FOSTER has resigned as district geologist for the Sinclair Oil and Gas Company in West Texas and is now engaged in consulting work in San Angelo.

JOHN T. LONSDALE, head of the geological department, Texas A. and M. College, College Station, addressed the San Antonio Geological Society, April 6, on "Conservation of Underground Water and Status of Underground Water

Situation in Southwest Texas." W. C. SPOONER, of Shreveport, Louisiana, addressed the society, May 4, on "The Stratigraphy and Recent Oil and Gas Developments of the New East Texas Field."

The tennis tournament which the San Antonio Geological Society sponsored for its members ended May 17. THORNTON DAVIS won the singles championship, in which CHARLES H. ROW was runner-up. CHARLES H. ROW and R. P. BREWER, JR., won the doubles championship; R. A. STEHR and W. E. SANDERS were runners-up in this event. The final matches were played on the Saddle Club courts.

ROBERT T. HILL, well known Texas geologist and now special oil editor for the *Dallas News-Journal*, spoke before the West Texas Geological Society, April 18, on the subject, "Cabeza de Vaca, America's First Geologist."

DOUGLAS R. SEMMES and Miss BESS SPEARS, of San Antonio, Texas, were married on June 11, 1931, at Laurel Heights Methodist Church, San Antonio.

The Colorado School of Mines, for the first time since the establishment of the department of geophysics in 1926, is offering a short course in geophysical prospecting, from July 27 to August 21. It will be a general resumé of the four major special courses in torsion-balance, seismic, magnetic, and electrical prospecting. Registration closes June 25. For further information write to Professor C. A. Heiland, Golden, Colorado.

The Fifth Annual Field Conference of the Kansas Geological Society will be held August 30 to September 5, 1931, in the Wichita and Arbuckle Mountains of Oklahoma and the Ouachita Mountains of southeastern Oklahoma and western Arkansas. For details, write to N. W. BASS, chairman, 919 Central Building, Wichita, Kansas.

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